Measuring the Impacts of Freight Transportation Improvements on the Economy and Competitiveness

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16. Abstract This document provides a review of approaches, methods, and tools that can be used to evaluate how freight improvements contribute to economic competitiveness and the cost of goods. The information within is intended to serve as a point of reference to assist practitioners, particularly state and regional transportation decision makers, in considering how freight improvements contribute to the economy. The document provides an overview of the methods used in this area that is not overly technical and is designed to be accessible to a range of practitioners in different disciplines, including engineers, planners, and policymakers. It is expected that this document will be of interest to members of State DOTs, MPOs, Federal agencies, and other stakeholders interested in freight transportation and economic development.			
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Acronym / Abbreviation	Stands For
3PL	Third party logistics provider
AASHTO	American Association of State Highway Transportation Officials
BCA	Benefit Cost Analysis
CDSS	Congestion Decision Support System
DOT	Department of Transportation
EDRG	Economic Development Research Group
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
HERS-ST	Highway Economic Requirement System - State
IDAS	ITS Deployment Analysis System
IMC	Intermodal Marketing Company
IMPLAN	IMpact analysis for PLANning
I-O	Input-Output
LEAP	Local Economic Assessment Package
LTL	Less-than-Truckload
MPO	Metropolitan Planning Organization
NAICS	North American Industry Classification System
PECAS	Production Exchange Consumption Allocation System
REMI	Regional Models Incorporated
REIMHS	Regional Economic Impact Model for Highway Systems
RIMS II	Regional Input-Output Modeling System II
RUBMRIO	Random Utility-Based Multiregional Input-Output
SAM	social accounting matrices
SEMCOG	Southeast Michigan Council of Governments
STEAM	Surface Transportation Efficiency Model
SHRP	Strategic Highway Research Program
TELUM	Transportation Environment and Land-use Model
TL	Truckload
T-PICS	Transportation Project Impact Case Studies
TREDIS	Transportation Economic Development Impact System

1. INTRODUCTION

This reference document serves as the final report for Federal Highway Administration's (FHWA) project to examine economic competitiveness and cost in relation to freight movement. To inform this document, a literature review and white paper that considered the concept of competitiveness in relation to the concept of economic productivity was developed. The white paper identified different freight performance measures and economic factors and discussed their linkage. It also reviewed a broad range of models that have been used to analyze the benefits and economic impacts of transportation improvements. A technical memo provided information sorting economic tools by type and an evaluation of those models that are most relevant to measuring the productivity impacts of freight improvements. In addition, a reference document was developed for practitioners discussing the different classes of benefits, economic impacts, and different models and tools for analyzing them. This document pulls together the research from all the tasks. While there is considerable emphasis in this document on the important economic impacts of freight transportation improvements on competitiveness and economic productivity, other types of economic impacts are also discussed. This document thus reviews three different types of analyses: 1) benefit-cost analysis (BCA), 2) economic impact assessments, and 3) analyses focused on estimating the impact of transportation on industry productivity and competitiveness.

1.1. How to Use this Document

This document provides a review of approaches, methods, and tools that can be used to evaluate how freight improvements contribute to economic competitiveness and the cost of goods. The information within is intended to serve as a point of reference to assist practitioners, particularly State and regional transportation decision-makers, in considering how freight improvements contribute to the economy. The document provides an overview of the methods used in this area that is not overly technical and is designed to be accessible to a range of practitioners in different disciplines, including engineers, planners, and policymakers. It is expected that this document will be of interest to members of State departments of transportation (DOT), metropolitan planning organizations (MPO), Federal agencies, and other stakeholders interested in freight transportation and economic development. FHWA recognizes that understanding how freight improvements contribute to economic competitiveness and cost is an emerging area. Traditional means of economic analysis and valuation may not always fit in analyzing freight projects. However, this work is intended, in part, to collect information on how to approach these analyses and recommend some options and tools. The document is not intended to be comprehensive, but rather to serve as a starting point for understanding the means for economic analysis that can be used to consider the benefits of freight transportation improvement.

Section 1 introduces the document and provides an overview of overall effort. It also describes the different uses this document may have. First, it will help agencies or consulting firms to select the best tool for a given analysis or project. Second, it will be useful in helping agencies that wish to hire a consultant to evaluate responses to requests for proposal (RFP) so they can select a team that uses the most appropriate tool. Finally, this document provides a starting point for presenters (agency staff, consultants, etc.) to describe what a given "t" analysis can tell the audience and what a method or tool cannot capture.

Section 2 discusses and defines of the economic concept of competitiveness and how freight transportation is related to it. It describes how freight transportation improvements affect mode choice, the productivity of the supply chain and the competitiveness of businesses. In addition, Section 2 discusses three types of freight transportation impacts: direct user benefits, economic development, and productivity improvement. It considers the linkage between direct user benefits, as measured by performance measures, with economic development and the more long-term productivity improvements that help to drive economic growth.

Section 3 provides a list of factors and considerations for review when planning an economic analysis of a freight transportation investment.

Section 4 gives readers an overview of the approaches and some modeling tools to conduct benefit cost analyses, economic impact analyses, and productivity (competitiveness) analyses for freight transportation projects. In addition, simplified methods to address these approaches are also discussed.

Section 5 offers an overall summary of these methods and describes some of their strengths and weaknesses.

2. FREIGHT TRANSPORTATION AND COMPETITIVENESS

Policymakers are often interested in making transportation improvements to their region to improve the competitiveness of their economy. The link between competitiveness as it is popularly understood and the terms and concepts used by economists is worthy of further clarification.

"Competitiveness," as such, is not an established term in the lexicon of economics. It came into common use in the 1980s, when there was considerable public discussion about the rise of Japan as an exporting power and the rising tide of imports of manufactured goods began flowing into the United States. The term was generally used to mean the ability to compete with manufacturers in other countries. It was never precisely defined in economic terms; however, it is important to define competitiveness in clear economic terms so that it becomes measurable. It is also the case that thinking of economic performance only in terms of international competition is too narrow a concept.

When policymakers talk about improving competitiveness as a goal, they are usually seeking to promote the expansion of businesses within their geographic region. Freight transportation improvements can serve this goal through several avenues. Improvements in freight transportation can reduce freight transit times, improve the reliability of freight shipments, and reduce the cost of freight transportation. Reduced transit times can allow businesses to access suppliers in a larger market region or sell their products into a larger market area. Improvements in the reliability of transit times can allow businesses to reduce inventory levels and rely more on just-in-time shipments, reducing their total logistics cost of production. Freight transportation improvements that enable businesses to produce products with lower total input costs will allow them to achieve a relative advantage against other firms who have higher costs. Reducing the total logistics costs associated with obtaining supplies and moving finished goods to market improves productivity by allowing businesses to produce more with fewer resources. Access to low-cost suppliers can also reduce input costs. Businesses may either pass these savings on to consumers or retain them as profits, or some combination of these. If the savings are passed on to consumers through reduced prices, this may allow businesses to increase demand for their products, capture market share and expand production. Freight transportation improvements thus enable competitiveness by improving productivity. Increased competitiveness creates opportunities for business growth and expansion.

Infrastructure, a Pillar of Competitiveness

"Extensive and efficient infrastructure is critical for ensuring the effective functioning of the economy, as it is an important factor in determining the location of economic activity and the kinds of activities or sectors that can develop within a country. Well-developed infrastructure reduces the effect of distance between regions, integrating the national market and connecting it at low cost to markets in other countries and regions."

—World Economic Forum, The Global Competitiveness Report 2014-2015, Available at: http://reports.weforum.org/global-competitiveness-report-2014-2015/

By expanding market access to suppliers and customers, improved freight transportation creates more competition for all businesses affected. Over the long run, this enhanced competition can also lead to greater efficiency as all market participants are compelled to innovate and lower costs in the presence of additional competitors.

"Productivity" and "economic efficiency" are the terms associated with the total value of goods and services produced in relation to the resources required to produce them. Since we are talking about the effectiveness of the freight system, we are not concerned with production of services—only with production and distribution of goods. In a loose sense, we are talking about the "biggest bang for the buck," but we have to be careful about what we mean. We are concerned with the quantity and the quality of goods produced with available resources. It is not just the quantity of widgets being made; it is also about the satisfaction people get from using those widgets. A more productive economy doesn't just produce *more* widgets, it produces *better* widgets.

As U.S. manufacturers become more productive, they are better able to compete in global markets. But that is only part of the story. As the domestic manufacturing and distribution systems become more productive, the nation's standard of living rises. More and better goods are available to consumers using the same levels of labor and capital. These are, if you like, more competitive goods, so more of them are likely to be exported. One effect of rising exports is that consumers get to choose among a wider array of goods, from both foreign and domestic sources.

Competitiveness and Productivity Intrinsically Linked

"For a given industry in a region, productivity and competitiveness are intrinsically related, for productivity may be viewed as the ratio of [output produced per unit of input cost] and cost competitiveness is measured through the ratio of [input cost per unit of output produced]. Thus, productivity can be viewed as a driver and an indicator of net national economic impact (affecting economic growth net of business relocation effects)…"

Greater productivity leads to a higher standard of living. So to consider how transportation improves competitiveness, we focus here on measuring the impacts of transportation on productivity. Improving the productivity of businesses within a region provides a relative competitive advantage over firms located elsewhere. The focus on productivity gives us more precise economic terminology and a broader view of the benefits of a more efficient economy. In economic terms, productivity and efficiency have essentially the same meaning. For simplicity's sake, we will use the term "productivity" in this document.

2.1. Logistics and the Efficiency of the Supply Chain

Investments in the freight transportation system help to improve productivity by allowing for improvements in logistics. Logistics is the management of the supply chain. It includes managing the flow of goods, information, and other resources between the point of origin and the point of consumption in order to meet the requirements of consumers. Logistics management activities typically include inbound and outbound transportation management, fleet management, warehousing, logistics network design, inventory management, and supply/demand planning. Logistics management also addresses issues such as sourcing, procurement, and production planning.

Logistics is essentially about freight carriage and inventory. Put another way, it is about the supply chain and the efficiency of the supply chain. Supplies of raw materials, parts, and intermediate products have to be moved from sources to plants where goods for sale to customers are produced. (Note that not all goods are sold to consumers. Some are sold to firms for use in production of goods or services.) Plants have to hold some level of supply in inventory to keep production going smoothly. Finished goods have to flow from plants to customers, but relatively few sales are direct from the factory. Generally, the flow is from plants to distribution centers (warehouses) where inventory is held either by wholesalers or retailers and thence to retail outlets where, again, inventory is held.

The major components of logistics costs are transportation, interest rates (on inventory), and costs of obtaining and operating distribution centers.[1] Highway-freight performance affects all three of these costs. To understand why this is the case, we need to understand how firms—manufacturers, distributors, and retailers—think about inventory. Inventory is a cost; it requires investment of capital to hold a stock of goods at a given level. Firms choose the level of inventory carefully. It is not just a matter of minimizing cost. There are significant trade-offs between the interest cost of a given stock and the potential costs of holding too small a stock.

For a manufacturing firm, the risk is shutting down production for lack of materials or parts. The firm must consider the probability that a critical input does not arrive on time. It estimates that probability and chooses a level of stock accordingly. The greater the probability of delivery failure, the larger the extra ("buffer") stock the firm must hold, which increases its inventory cost.

At the downstream end of the supply chain, the retail operation, the situation is a bit more complex. Retailers also have to hold buffer stocks to avoid the risk of running out of an item and thereby losing sales. They also make a judgment based on the probability of delivery failure. But a retailer also has to think about the variety of items he carries in stock. If he holds only items with high turnover, he will miss some sales. Some customers want the slower moving items, or want them occasionally, and may take their business to the place that carries them. The retailer makes a judgment on the trade-off between higher inventory cost and additional revenue gained from holding a wider variety of goods and, accordingly, chooses his inventory level.

Distribution centers may be owned either by wholesale distributors or large retailers. In any event, they must hold some buffer stock at these centers to ensure ability to meet promptly demands from retail outlets.

Highway-freight performance affects all components of logistics costs—transport costs and inventory costs. Improved highways directly reduce the cost of carriage. Reduced congestion reduces transit times and unexpected delay; it also reduces vehicle operating costs. There are two main effects on inventory cost. Reduction in unexpected delay translates to increased probability

1 We focus here on the largest logistics cost components for all commodities. Note that there are other logistics costs, including spoilage or other costs associated with perishability that can be significant for some commodities.

of on-time delivery and, thus, reduces the amount of buffer stock needed. Transport costs also affect the number of distribution centers required. If transport costs fall relative to interest rates, shippers will opt for longer hauls and fewer distribution centers. Fewer distribution centers usually lead to reduced inventory levels. As more stores are served from a given center, there is some reduction in buffer stock per store. Conversely, when transport costs rise relative to interest rates, there is a tendency towards shorter hauls and more distribution centers.[2]

It is important to note that highway performance also affects intermodal movements as well. Global supply chains involving the movement of containers by multiple modes are sensitive to delays anywhere in the supply chain. Changes in highway performance thus affect the competitiveness of U.S. export and import supply chains that involve intermodal movements by marine, air, rail, and truck modes.

The main point here is that improved highway-freight performance increases efficiency all along the supply chain and, thus, increases the efficiency of manufacturers, distributors, and retailers. It is also important to note that the supply chain is never static. All the firms along the supply chain are constantly watching changing transport, labor, land, inventory and other costs and factors and acting accordingly when they make new location decisions for factories and distribution centers.

2.2. Mode Choice

As we consider the efficiency of the supply chain, we need to bear in mind issues about choice of mode. All along the supply chain, shippers make decisions about which mode to use for moving their goods. The choices they make, and their reasons in choosing, are important to agencies making decisions about transportation investment projects. When considering possible projects in a given traffic lane, decision makers should know which modes are currently used and whether a particular infrastructure investment is likely to change the modes shippers use. Therefore, we include a discussion of mode choice in this section.

In domestic freight movement, the central mode-choice decision is between rail and highway carriage. For the highest-value traffic, there are cases where the choice is between air and highway (The 2007 Commodity Flow Survey (CFS) shows goods carried by air as less than 0.1 percent of total freight tonnage). Traffic moving by air typically comprises highly perishable goods—cut flowers would be one example—or very high-value goods needed quickly. Traffic of this kind is a very small percentage of total freight tonnage. For the lowest value traffic, e.g., coal and grain, there are cases where the choice is between rail and barge. Coal and grain account for 15.4 percent of total tonnage on all modes. Bulk commodities such as coal and grain will not be shipped by highway any farther than necessary to reach a rail connection or a river loading point. Their low value per ton does not justify higher transportation cost.

A significant fraction of the traffic between these extremes of high and low value might move by either highway or rail, but by no means all of it. An important issue is length of haul. It is difficult to fix with precision the minimum length of an intermodal haul, but rail would not be a viable option for nearly all traffic moving less than 300 miles. Intermodal moves have been getting shorter in recent years, and hauls in the 400-500 mile range are not uncommon. The 2007

2 In recent years, residential development in some urban areas has reduced the amount of land available for industrial and logistics related facilities. Policymakers in some areas have recognized the need to preserve land for these facilities near key freight routes.

CFS shows that 44.0 percent of inter-city for-hire truck tonnage was on moves between 50 and 250 miles. On this basis, we can safely say that rail carriage is not a viable option for more than 50 percent of for-hire tonnage. (Private carriers are unlikely to use their own fleets for intermodal drayage.) This leaves a large volume of traffic for which rail could be an efficient choice.

In order to understand the factors that drive mode choice, it is helpful to know something about this part of the market for freight carriage. Rail-freight service is available in three principal forms:

- Unit trains for bulk commodities.
- Intermodal—unit trains carrying containers and trailers.
- Carload service—also known as mixed trains.

A unit train is loaded at one point and moves to another point where it is unloaded. The entire train, typically 100 cars or more, consists of the same type of equipment. In the case of bulks, the train is carrying only one commodity—a coal train, a grain train—or, more recently, a train carrying crude petroleum. In these cases, the whole train is a single shipment. As noted above, highway carriage is uneconomic for shippers of these commodities; their mode choice, if they have one, would be between rail and barge.

An intermodal train, however, carries many shipments; every trailer or container is an individual shipment. But the intermodal train is a unit train in the sense that, generally, the whole train is comprised of the same/similar equipment and is loaded at one terminal and then unloaded at the destination terminal. (There are variations; part of an intermodal train, for example, is sometimes dropped at one terminal, with the rest being dropped at the destination terminal.)

Carload service is available only at locations on a siding. A typical carload shipper might load, at most, three cars at a time. These cars are gathered by local trains and brought into a classification yard where the cars are placed in various outbound trains according to their final destinations. Getting a shipment to a final destination usually entails movement through two or more intermediate terminals before reaching the destination terminal. At each intermediate terminal, inbound trains are broken up and cars placed in various outbound trains. From the destination terminal, local trains take shipments to their final destinations. These are slow movements; a car is likely to sit for a day in each terminal before it moves on in the next train. And the number of movements between terminals and the complexity of the sorting process in each terminal provides plenty of occasions for unintended delays. With a few exceptions (auto parts, chemicals), this is low-value traffic and not time sensitive.

Of these three types of rail service, only intermodal is a viable option for the great preponderance of shippers who would otherwise use all-highway carriage.[3] We also need to understand the types of trucking service available to shippers. This is shown in the following table.

3 Rail carload service can have a significant cost advantage for longer hauls, but this advantage is often eroded by actual equipment utilization, route circuitry, and pickup and delivery expenses. Because many destinations are not rail-served, incremental handling and truck delivery add to rail costs. Other logistical expenses rise due to the large size of rail deliveries, the slower transit, the unreliability and the higher incidence of damage.

Table 1. Types of trucking services available to shippers.

<table>
<tr><th colspan="3">Inter-city Trucking</th></tr>
<tr><td colspan="2">For-hire</td><td rowspan="2">Private carriage</td></tr>
<tr><td>Truckload</td><td>Less-than-truckload (LTL)</td></tr>
</table>

Private carriage is the practice of shippers moving their own goods in their own fleet of trucks. Usually, it is somewhat more costly than for-hire truckload service. Shippers use private carriage to maintain tight control over their shipments and to minimize the probability of delivery failures. A private carrier is unlikely to maintain a large enough fleet for all its transport requirements. It would use for-hire carriage in peak demand periods or for moves that do not fit well with the regular patterns of its own carriage. When a private carrier turns to for-hire service, it would consider the option of using intermodal service. A private carrier would be very unlikely to use its own equipment for the drayage move to an intermodal terminal.

In truckload service, a truck is ordinarily loaded at the origin point and proceeds to the destination where it is unloaded. It is the truckload shipper for which intermodal rail can be a viable option. In Less-than-Truckload (LTL) service, small shipments (average around 1,000 pounds)[4] are collected by local trucks, brought to a terminal where loads to various destinations are consolidated and carried over the road to their destination terminals. Local fleets at destination terminals make the final deliveries to receivers. Some over-the-road moves between LTL terminals are made by intermodal rail, but the decision to use rail is made by the LTL carrier, not by the shipper. (The largest single user of intermodal rail is UPS; but UPS, not its customers, decides how to move the packages.)

As noted above, length of haul is an important concern for a shipper. Shippers select railroads for long distance hauls because the pickup and delivery portion of a typical move costs about $700.[5] Spreading this fixed cost over a longer haul reduces the total per mile cost. We have to be a bit wary of stating an absolute minimum length for viability of intermodal. The “minimum” length has been coming down in recent years due to a number of factors, such as increasing fuel prices and improved efficiency in intermodal operations. Further, the minimum will vary according to a shipper’s location, the length of the drayage moves at either end of the trip, and the volume of freight moved between two points. Under current conditions, a rough generality would be that few hauls under 400 miles would be viable and nearly zero under 300 miles. The next threshold is whether the intermodal service available to a shipper fits its existing supply-chain network. Factory and warehouse location decisions may well have been made without regard to rail service. So the corridors in its supply-chain network may not be well served by the available intermodal terminals.

When the existing supply chain and length of haul are compatible with intermodal service, a shipper considers price and service quality when making the choice of mode. Price for intermodal service is typically lower than for all-highway service, so the issue really comes down to quality of service and proximity to major intermodal terminals. Service quality has two

4 S.V. Burks, M. Belzer, Q. Kwan, S. Pratt, and S. Shackelford, “Trucking 101: An Industry Primer,” Transportation Research Circular E-C146 (Washington, DC: TRB, December 2010). Available at *http://onlinepubs.trb.org/onlinepubs/circulars/ec146.pdf*.

5 N. Perry. The State of Truck/Rail Modal Share: An Analysis for Transportation Customers, sponsored by U.S. Express Enterprises (Transport Fundamentals, Inc., April 2010). Available at: *http://www.usxpress.com/~/media/Files/Featured%20Documents/Truck%20Rail%20Study.ashx*.

components: transit time and reliability. Generally, transit time for intermodal will require at least an additional day; loading and unloading intermodal trains requires approximately a half day on each end.[6] More importantly, there will be some time lag from the time a container or trailer is dropped at the intermodal yard and the loaded train ultimately departs. The phrase "intermodal is highway plus a day" is often heard as a rough rule of thumb. Improvements in intermodal service are reducing transit times in some lanes, but it will be almost always slower than truck. (Likeliest exceptions would be in lanes with frequent highway congestion and high frequency of intermodal train departures.) Also, the time penalty for intermodal is reduced as length of haul goes up. This would be especially true for trips longer than one driver can do in a day. Another cost associated with intermodal is that intermodal freight needs to be loaded differently. There is a need to put more blocking and bracing in to keep the load from shifting because of the slack action and the lifting on and off of the flatcar.

In any event, many shippers can tolerate the longer transit time of intermodal carriage. For them, reliability is the key question. In this context, reliability means delivery before a fixed time. Often, it also means delivery not before a fixed time; the delivery must be made in a certain time window, often referred to as "just-in-time." Given a cost advantage for rail and an acceptable transit time, shippers will choose rail when they are confident the rail carrier can meet truck standards of reliability—often as high as 95 percent on-time performance. Some industry observers report that intermodal reliability has been increasing in recent years.[7]

Most of this discussion has been in terms of choices made by shippers. We have noted that LTL carriers and package carriers choose the mode for those kinds of service. Frequently, this is also the case when a shipper turns traffic management over to a third-party logistics (3PL) provider.[8]

The 3PL has to meet certain conditions regarding cost and service quality but can make its own choices within those constraints.

It is also worth noting that shippers or 3PLs using intermodal usually do not deal directly with the rail carrier. Much of the intermodal service retail sales are made by intermodal marketing companies (IMCs). The shipper never talks to the railroad; the IMC arranges the dray at both ends and bills the shipper for the entire move. Some large truckload carriers provide intermodal service in the same way; the trucking firm makes all the arrangements with the railroad, and the shipper gets one bill and one set of shipping documents.

Understanding mode choice is critical to properly characterizing the relationship between freight transportation, cost, and economic competitiveness. Improvements in transportation infrastructure occur within the context of a multimodal transportation system. Where shippers have access to an intermodal option, freight traffic can shift between transportation modes in response to relative cost or service improvements. Shippers also have an interest in sourcing transportation from multiple modes to maintain the resilience of their supply chain. Many

6 Joseph Bryan. Measuring Freight Fluidity Performance, Briefing on Work of DOC Advisory Committee on Supply Chain Competitiveness & FHWA/I-95 Pilot. ITTS Freight in the Southeast Conference – Tampa, FL, March 2014.

7 Improvement in intermodal service is based on information from the team's industry and academic contacts. The information on factors considered in mode choice is, in part, from "Inhibitors to Rail Carload and Intermodal Market Share Growth," a 2009 report by Norbridge, Inc. The team's industry and academic contacts confirm the essentials of the Norbridge findings.

8 A 3PL is a firm that provides multiple logistics services for use by customers. Preferably, these services are integrated, or bundled together, by the provider. Among the services 3PLs provide are transportation, warehousing, cross-docking, inventory management, packaging, and freight forwarding. In freight transportation, 3rd party logistics providers serve a market niche by consolidating and organizing shipments across a variety of modes.

shippers will thus utilize multiple modes of transportation (and service providers) to ensure that they are not overly reliant on a single entity for transportation. It is important to consider potential mode shifts when estimating the economic benefits of transportation improvements. The discussion above also illustrates that mode choice is an economic decision that is complex, influenced by numerous institutional and market factors, and not easily predicted by merely the price of transportation services available.

2.3. Typology of Economic Impacts

Benefits and impacts of an investment—a project or a set of projects—can be placed in three basic classes:

- Direct user benefits.
- Economic development—income, output, employment.
- Productivity.

At first glance, the distinction between economic development and productivity may seem artificial, but it is not. Economic development is about increases in economic activity: more production, more jobs, more income, and more spending. This turns into increased economic well-being for some or most of the population in the affected region. Productivity is about the efficient use of resources in producing goods and services. Output, for example, can increase just because demand increases due to a population increase. If output rises only in proportion to population, the standard of living stays the same, even though the total level of economic activity has risen. If resources are used with greater efficiency, the ratio of output to cost rises and the standard of living rises. These are thus two distinct types of impacts, and they are measured differently.

Direct user benefits are the immediate effects on users of a facility—speed, safety, and other factors. As noted above, economic-development impacts are in the form of output, employment, income, and similar aspects of economic activity. Productivity impacts are output per units of labor and capital. Table 2 provides more detail on the measures of these classes of impacts.

Table 2. Typical public sector highway performance metrics.

User Benefits			Economic Development	Productivity
Time	Operating Cost	Safety		
Average speed	Labor	Crash rate	Goods produced	Per man-hour
Transit times	Fuel	Fatality rate	Services produced	Per $ of capital
Congestion	Maintenance	Injury rate	Business revenue	Labor/capital combined
Incident-based congestion	Loss & damage		Income	
Weather-based congestion			Employment	
On-time arrival			Investment	
Transit-time variance				
Delay				

Time benefits are not just reduced transit times. They also flow from increased reliability as incident-based congestion diminishes. For a great many shippers, reliability is more important than transit time. Reduction in unpredictable congestion[9] increases consistency in travel times, but also reduces fuel and maintenance costs. Labor costs go down as transit times decrease and variance in transit times shrinks. Reduced transit-time variance[10] allows for more efficient use of drivers and vehicles. Less congestion, fewer crashes, and smoother pavement in turn decrease loss and damage. From the perspective of carriers and shippers, fewer crashes can mean somewhat lower rates due to lower insurance premiums. Decreased crash rates also mean some lessening of loss, damage, and missed deliveries.

These benefits are associated with highway improvement, but similar benefits could flow equally from an improved intermodal connection such as a new intermodal terminal that allows shippers to use intermodal rail. A shipper might or might not save time using intermodal rail, but there would be a cost reduction and a safety benefit. Shippers will accept some increase in transit times when using intermodal rail, if reliability is acceptable.

Economic development follows from lower costs and increased efficiency all along the supply chain. Shippers—manufacturers and distributors—experience an immediate impact in reduced cost of carriage. Reduced cost of carriage then leads to what are often called “reorganization effects.” As the cost of shipping drops, supply areas and market areas increase in size. Supplies can be drawn from a larger area and a given factory or distribution center can ship to a larger market area. Reliability gains allow smaller buffer stocks, further reducing logistics costs. Business revenues rise, income rises, and employment rises. This is the economic development effect.

Some of this effect stems from growth in firms in the region in question (organic growth), and some of it stems from relocation to the region as reduced costs makes it a more attractive location for some businesses. From the perspective of the region, it is all economic growth. From the national perspective, the effect from relocation is net zero or close to it. Growth in Region A is offset by reduced growth in Region B.

The role of improved transportation and logistics on job growth in the United States is a complex issue. In some cases improved freight transportation can encourage firms to use low-cost suppliers in other countries, which can lead to the creation of jobs overseas. Access to low-cost suppliers can be an important factor in allowing U.S.-based companies to be competitive, allowing firms to maintain or expand operations in the U.S. More broadly, increased trade encourages regions and nations to specialize in industries and economic activities where they have a comparative advantage. This leads to improvements in industry productivity over time and increases economic output.

Productivity is measured by the ratio of the dollar value of output to the dollar value of labor and capital inputs. Productivity improvements may occur for several reasons. For one, increases in supply-chain efficiency reduce costs; that is an immediate productivity gain. As economic development brings rising output, there may be scale economies leading to further productivity gains. Beyond that, increasing scale could change production technologies with additional gains.

9 Unpredictable congestion is primarily of function of vehicle crashes and other traffic incidents.

10 Variance in transit times can be measured with vehicle probe data. This data is derived from private sector sources, although some data has been made available for public sector performance measurement.

Federal Highway Administration (FHWA) is currently working with freight stakeholders to develop new freight performance measures that are focused on the overall performance of the supply chain as experienced by transportation users. These Freight Fluidity measures will combine measures of reliability, speed, and delay across the entire supply chain and provide an assessment of the performance of freight moving by multiple modes for a specific origin-destination. For instance, for a container freight shipment from China to a destination in the United States, a freight fluidity measure could include the time in transit on a container ship, the dwell time of the container in a port, and the time spent in transit by truck or rail to its final destination. Freight fluidity performance measures may provide an important tool to more effectively link transportation improvements to their economic impacts. These measures can also be used to benchmark trade routes and identify bottlenecks.

2.3.1. Linkage of Performance Measures to Economic Impacts

The following matrix shows some of the key linkages between performance measures and economic factors. It should be noted that increases in the value per ton of freight would tend to strengthen the relationship of the performance measures to the other economic factors discussed.

Some of these measures are closely related to each other, but we discuss them separately since they may examine performance from a different stakeholder perspective or in a different way. For example, it should be noted that the average speed and the transit time performance measures discussed below have similar economic impacts. The difference in these performance measures is in how they are measured and the perspective of the agency using the performance measure. The transit time performance measure is more often used by shippers, who focus on how long it takes to move a particular shipment between two points. The average speed measure is more often used by transportation planners, who are considering how investments in infrastructure can improve the performance of specific segments of the transportation network.

Reliability and transit time variance are also closely related performance measures. Reliability measures the unexpected congestion or delay on a specific roadway segment. This measure would typically be used by a transportation planner. Transit time variance provides a measure of performance from the perspective of the shipper, measuring the level of unexpected delay for the shipment.

There can be significant differences in what these performance measures capture. For instance, vehicle speeds are often measured for peak and off-peak traffic. If freight traffic moves disproportionately at night, improvements in peak speeds may have a smaller impact on truck traffic. Factors other than vehicle speeds on the network affect transit times. The hours-of-service rule for truck drivers is one example of this. A driver who has exhausted his allowable driving time will be required to stop. Transit time and average vehicle speeds measured on the network are thus not always related in linear fashion.

Because some of the performance measures discussed are closely related or overlap, there is also some overlap in the economic factors. It is thus important to note that not all of these factors are additive with each other, although some of them are.

Some of the economic factors are more easily measured than others. For instance, the average speed and transit time performance measures affects vehicle and driver costs for the truck, which affects the cost of delivering freight. These costs are traditionally measured in benefit cost analyses (BCA). Estimating driver labor costs is relatively straight-forward, as time savings can be translated into monetary values using estimates of average driver wages and benefits. There is also data available to represent the capital and operating costs associated with the truck. The cost of delay for the freight shipper and receiver is more complex, depending greatly on the type and value of the freight carried, and how the freight shipment is being used by the customer. The average cost of delay for freight can mask a wide range of costs for different commodities, consuming industries and customers.

Estimating how performance measures affect long term productivity improvements in industry is even more complex still. These effects include increasing the supply and market areas, providing access to lower cost or higher quality suppliers, allowing for improved inventory management and a more efficient supply chain. Over the long term, improvements such as these may allow for business reorganization, expansion and increased economies of scale. The table below summarizes the performance measures and the economic factors that can be linked to them.

Table 3. Key linkages between performance measures and economic factors.

Performance Measures	Economic Factors
Average speed	Size of supply and market areas. Higher average speeds may increase the geographic area from which supplies can be drawn and the effective market into which supplies can be sold. A larger supply area can mean lower-cost and/or better inputs. A larger market area means greater production in a given facility—thus, greater productivity.[1] It also improves access to and connection with the freight network.[2]
Reliability	A greater probability of on-time delivery reduces both production and distribution costs, due to lower buffer stocks.
Transit times in key freight lanes	Affects the size of supply and market areas for firms in regions served by those lanes. Reduces cost of carriage due to improved utilization of truck and driver. This reduces both driver labor costs and vehicle operating costs.
Variance in transit times	More predictable transit times means more efficient scheduling and improved utilization of truck and driver. Also, it creates a higher probability of on-time delivery and reduces the cost of reliable service.
Crash rates	Crash rates drive insurance costs, loss and damage of goods, and delivery failures.
Pavement quality	Smoothness of pavement increases speeds, reduces loss and damage, and lowers vehicle operating costs.

Table 3. Key linkages between performance measures and economic factors. (cont'd.)

Performance Measures	Economic Factors
Vehicle operating costs	Lower cost per mile reduces cost to shippers and increases supply and market areas.

[1] It should be noted that greater production does not automatically translate into greater productivity, but that economies of scale may become possible and attainable. Economies of scale can occur as the cost per unit of output decrease with increasing scale. This happens when fixed costs are spread out over more units of output. Economies of scale do have many limits, including exhausting nearby supplies of raw materials or saturating local consumption markets, requiring finished goods to be shipped further to generate new sales. Transportation costs thus play an important role in allowing scale economies.

[2] Improving vehicle speeds could improve access to the freight network by reducing the time and cost required to access an intermodal rail facility, making intermodal shipments more economically viable.

3. SELECTING THE RIGHT ANALYTICAL TOOL

Given the variety of methods available for transportation economic analysis, it is important to recognize that not all methods are applicable in all circumstances. There are a number of key factors that affect the appropriate selection of a methodology. The key questions that the analyst should consider are:

- What are the goals of the analysis?
- What data, tools, and resources do we have available?

3.1. What are the Goals of the Analysis?

The first question to consider is "What is the goal of the analysis?" Answering this question will typically include several components, including project type, freight modes considered, time horizon, geographic scope, outcomes measured, and precision required.

3.1.1. Project or Policy Type

The goals of the analysis are in part related to the type of project or policy. Does the agency wish to analyze the impacts of an individual project with local impacts or a larger project with regional or statewide impacts? Large-scale projects could cost hundreds of millions or billions of dollars and encompass numerous smaller projects. These could include large multimodal projects and corridor projects, such as new tuck roadway routes, tunnels, major interchanges, or overpasses. Projects with national impacts include investments in intermodal transportation, such improvements to the Alameda Corridor, which connects to the Ports of Los Angeles and Long Beach and handles nearly half of the containers entering the United States.

In some cases projects targeted to specific freight network segments could have broader impacts as well. For instance, improvements to intermodal freight connectors for key freight facilities could have broader impacts on intermodal freight transport. Investments in truck freight bottlenecks could have significant impacts on the interstate freight transportation network. Investments targeted towards the National Freight Network would be likely to have broad impacts. The national freight network includes the primary freight network, other portions of the Interstate System, and critical rural freight corridors. Investments in border crossings, such as the Blue Water Bridge Border Plaza, can be important conduits for trade that have national significance.

In a similar fashion, some transportation policies are of national significance. The Hours of Service Regulations and Truck Size and Weight regulations are examples of Federal policies that significantly affect the cost of moving freight. Significant changes in these rules could have national significance and have been analyzed using more sophisticated methods that can consider industry productivity impacts. Policies that affect regional or local freight operations have less significant impacts.

The types of economic impacts to consider are related to the scale of the project or policy, and are discussed further below. Direct user benefits can be measured with a benefit-cost analysis (BCA), and this may be appropriate for a smaller project level analysis. A more extensive economic analysis may be recommended for larger transportation infrastructure investments that will have significant economic impacts across a region. Simplified approaches might be recommended for projects that are not as significant.

3.1.2. Freight Modes Considered

A key analysis consideration is whether the benefits of regional transportation improvements are only considered in the context of a single mode such as highway or rail, or whether it is important to conduct a multi-modal analysis that considers the impacts of freight transport mode-shifts. For instance, investments in intermodal facilities could improve access to rail intermodal transportation options for shippers.

Typically the potential for mode shifts are measured by analyzing data on commodity movements and determining what share of freight may have competitive alternative modes of transportation. This analysis would incorporate the type of cargo, length of haul, value and volume of freight. Availability of infrastructure and alternative transportation services must also be taken into account. Statistical models, expert judgment, or the combination of the two can be used to determine the probability that freight of different types could be shifted to an alternative mode based on changes in transit time, cost, or reliability. For some applications, off-the-shelf models may be available as well.

If the impacts of a proposed project or policy are small or otherwise unlikely to have a significant impact on the choice of transportation mode, it may be appropriate to omit this analysis.

3.1.3. Time Horizon

Project and policy benefit cost analysis (BCA) can use an analysis time period of 20 years or more. If an infrastructure project is being analyzed, the analysis time period specified can be influenced by the expected life-span of the infrastructure. Some projects, such as investments in ITS, may have a lifespan that is shorter than 20 years.

Even if a project or policy does not have a specific lifespan, when project benefits are discounted in the future, adding to the length of the analysis period will result in smaller and smaller increments of benefit. The time period can often be restricted based on the fact that most benefits will accrue in the early years of the analysis. Lengthening the time period of the analysis also increases the uncertainty associated with the benefit and cost estimates, as it becomes more difficult to predict what will happen and the assumptions on which the analysis is based are more likely to change.

The time horizon considered also has an important impact on estimating the productivity benefits of a policy or project. In the short term, a project may have direct benefits to the current users of the facility. Over the long term, businesses may reorganize their supply chain to adjust to changes in transportation costs. This reorganization can lead to additional productivity benefits to the economy and provide additional demand for freight transport. These benefits would typically not occur in the first year of the analysis time period, but would require a number of years for the benefits to emerge as businesses adjust their operations.

As an example, if a lane is added to a roadway and reduces congestion, existing traffic will experience an immediate time and cost savings. In the near future businesses can adjust operational and tactical business decisions relatively quickly to take advantage of changes in the price of transportation. A carrier might adjust delivery routes to improve transit time for their trucks if congestion and transportation costs are reduced.

Some decisions, such as the location of facilities or strategic decisions about the structure of the supply chain cannot be changed easily in a short period of time. Nonetheless, businesses do make long-term decisions based on what they believe will happen in the economy and with future transportation prices.

Public policies can also have important long-term effects. The deregulation of the trucking and rail industries has caused transportation rates to fall significantly in inflation-adjusted terms since 1980. As a result, there has been a shift in the long-term demand for transportation. Many manufacturing industries have restructured their operations to use just-in-time inventory management. The economy has become more reliant on international trade and the movement of supplies and finished products from locations across the globe. The productivity impacts of changes in transportation costs can be very important, but may take years to emerge.

3.1.4. Geographic Scope

The methods and tools selected and approaches used may differ based on whether the scope of the analysis is focused on a State, a region, or a specific transportation corridor. It is important to consider how and where economic benefits will be produced. For instance, will businesses relocate from other regions, subtracting economic growth from other areas? Will it be important to account for these impacts? Will it be important to account for benefits that may accrue to regions other than the target region?

3.1.5. Outcomes Measured

There are a number of different outcomes that can be measured. These include the costs and benefits to the direct users of the facility, such as time savings, vehicle operating costs, and safety, as well as the more diffuse benefits that impact a larger population, such as air quality impacts. In addition to direct benefits, there are larger indirect and induced impacts to the economy that generate output and employment impacts. Another level of analysis might consider the longer term productivity impacts and future impacts on industry and regional competitiveness that investments might create. Data for some of these outcomes may be more readily available than others. It is important to note that not all of these outcomes are additive. Proper documentation and presentation of what these outcomes measure is important to ensure that readers interpret the results correctly. The selection of the analytical approach or specific model is driven in part by the types of outcomes that policymakers need to estimate.

3.1.6. Precision Required

The level of analytical precision required can range from extremely detailed studies that are performed to satisfy legal mandates to less precise sketch planning analyses whose purpose is simply to develop an initial estimate of the benefits. For instance the Montana Legislature mandated the inclusion and consideration of economic development issues in transportation planning and funding. In response, Montana Department of Transportation (DOT) created the Highway Economic Analysis Tool (HEAT) model in 2004 to estimate the economic development and industry productivity impacts of transportation investments. Larger projects typically require more rigorous analysis methods, while less effort would likely be expended studying smaller investments. A controversial project could require a more in-depth and sophisticated analysis to satisfy public demand for information.

3.2. What Data, Tools, and Resources are Available?

3.2.1. Data Availability

The availability of data is an important consideration for an agency that is conducting and an economic analysis of a freight transportation infrastructure investment. National data sources such as the Freight Analysis Framework (FAF) or the Commodity Flow Survey (CFS) can provide data on commodity flows in and out of States and regions by mode. In addition, the FAF contains data on truck volumes by segment for the highway network and includes data for the following roadway types: Interstate Highways, other FHWA-designated NHS routes, National Network (NN) routes that are not part of NHS, other rural and urban principal arterials, intermodal connectors, rural minor arterials for those counties that are not served by either NN or NHS routes, and urban bypass and streets as appropriate for network connectivity. FAF allocates freight to five truck types, which are single unit trucks, truck plus trailer combinations, tractor plus semitrailer combinations, tractor plus double trailer combinations, and tractor plus triple trailer combinations. While the FAF estimates empty trips for vehicles that carry freight, it does not estimate trips for trucks that are not engaged in freight carriage, such as utility trucks and business service vehicles. While the FAF data provides a comprehensive picture of freight movement among States and major metropolitan areas by all modes of transportation, allocating freight flows to smaller geographies is more difficult. In addition, it is important to be aware of the coverage and limitations of national data sources.

Depending on the nature of the regional economy and the goals of the study, these data gaps may be more or less important. For instance, the FAF does not provide local detail or temporal (seasonal, daily, or hourly) variation in freight flows that are typically necessary to support project planning. While statistical methods exist that allow analysts to disaggregate FAF data from FAF regions to counties or smaller areas, FHWA has not reviewed any of these methods in detail to determine their reliability or accuracy. FAF estimates of truck tonnage and number of trucks on the network, particularly in regions with multiple routes or significant local traffic between major centers of freight activity, should be supplemented with local data to support local applications.[11]

Some State or local planning agencies may have more detailed data on truck movements in a region. These data may be purchased from vendors (such as the Global Insight Transearch data), obtained from surveys, or derived from truck models. If detailed data is readily available, it may affect the decision of what type of approach to use. For instance some models discussed in section 4 can take advantage of detailed commodity flow data.

11 Federal Highway Administration, Freight Analysis Framework 3 Users Guide (Washington, DC: FHWA, June 2012). Available at: http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/userguide/index.htm#s12.

In many cases regional transportation agencies may spend more effort estimating and forecasting light-duty vehicles. Less data is typically available to understand medium and heavy-duty truck movements, which must by estimated using different methods than those used for passenger travel. Larger metropolitan regions and States may have invested in developing truck models, truck trip tables or detailed data on freight movements based on publicly available data from sources such as the County Business Patterns, data on land use, and other sources. Typically, economic activity as characterized by land use, employment or economic output is used to estimate truck trip origins and destinations (or the generation of freight tonnage, which is then converted into truck trips). Where truck movements connect to other modes, data from the Carload Waybill Sample, Waterborne Commerce Statistics, or other data sources may be used to estimate trucks carrying intermodal shipments. Many States and regions have not invested in developing detailed data on local truck movements. As a result, data constraints may be important to consider when selecting a tool for or approach to analyzing the impacts of freight transportation improvements on the economy.

3.2.2. Applicability of Shortcuts and Rules of Thumb

Some transportation agencies have developed simplified methods or rules of thumb that they use to conduct abbreviated economic analyses. If agencies are engaged in a sketch planning type of analysis, they may find that these simplified and abbreviated forms of analysis are perfectly adequate for obtaining the answers they need. For instance, SEMCOG has developed a simplified spreadsheet tool that incorporates elasticities from their economic model. The tool simplifies the economic analysis process for projects. The Minnesota DOT has developed guidance, a spreadsheet template, and sample values that are used to streamline the performance of BCAs. Rules of thumb for evaluating the transportation impacts of infrastructure investments are also available from a number of different sources, and these are discussed in Section 4.

3.2.3. Modeling Tools

The types of tools that agencies are currently using may influence what tools they choose to analyze the impacts of freight transportation improvements on their economy. Modeling often occurs in a two-step process. Transportation impacts are often represented in a travel demand or freight model. The outputs of transportation models then serve as the inputs to an economic model to estimate economic impacts. States and regional transportation agencies vary significantly in both the economic and transportation models at their disposal. While many larger MPOs have transportation demand models, the freight components of these models are less well developed or non-existent in many areas. States also vary substantially in the extent to which they have freight models. While some States have developed integrated modeling frameworks to estimate the economic benefits of improving freight transportation, many States do not have well developed modeling tools.

While not having dedicated freight models, some State or local transportation agencies may be active in using economic models to estimate the impacts of transportation investments, estimating the direct, indirect and induced impacts of expenditures. Agencies that are already using private commercial models may have State or local economic data, and models that can be used with marginal additional investment of resources to purchase software, train staff, or obtain data. Taking advantage of existing modeling tools may thus be an important consideration for model selection for many agencies. It is important to note that without a freight model, customized approaches may be needed to represent transportation impacts in economic impact models that cannot model freight flows on their own. Smaller agencies will typically have fewer resources and may not have conducted similar economic modeling projects in the past. Relying on simplified methods may be an attractive option for some of these agencies.

3.2.4. Resources: Budget and Staff Skills

Transportation or economic models may require a substantial financial investment in software licenses. In addition, an investment in staff time and training may be required to allow agency staff to use these models. Beyond the technical knowledge needed to navigate the software and develop data inputs, having access to a trained economist is usually desirable to ensure that model results are interpreted correctly. In many cases, a trained economist who is familiar with economic models can use creative solutions to represent transportation and logistics investments and incorporate their impacts into the model. This may be especially important if there are data gaps or limitations that must be overcome, or if the agency wishes to represent complex supply chain impacts and the industry productivity improvements that may be made possible by improvements in freight transport efficiency. The budget and staff skills available to an agency are often important factors in determining what types of tools are best to answer specific policy questions.

4. TOOLS AND TECHNIQUES

This section discusses three types of analyses that may be used to consider the impacts of freight transportation projects: benefit cost analysis (BCA), economic impact analysis, and regional productivity (competitiveness) analyses. A discussion of the goals, basic methods and tools available for each of these analytical frameworks follows. It is important to note that discussion of these tools does not provide an endorsement for any specific software tool or approach. This section provides an introduction to tools and methods that are available and in-use, but users will need to make their own evaluation to determine if any of these approaches or tools meets their needs.[12]

4.1. Benefit Cost Analysis

The BCA is an important tool for planners to determine whether investments in transportation infrastructure are economically and socially beneficial. It provides a standardized method for policymakers to assess the value of different types of benefits occurring at different points in time. Conducting a BCA is one way for planners to view the benefits and costs of transportation investments from a more global and all-encompassing perspective, rather than just looking at local impacts. In addition, by making the assumptions and analyses of public sector agencies more explicit, BCAs can help public-sector agencies communicate their planning perspectives to the stakeholders in the planning process.

4.1.1. Relationship of Travel Demand Modeling to Benefit Cost Analyses

Travel demand modeling serves as the foundation for many BCAs, particularly for larger projects that will cause regional effects on traffic. The outputs of travel demand models provide estimates and forecasts of highway performance measures under different scenarios. These include forecasts of traffic volumes, travel time, and delay by segment, which are the basis for estimating the benefits of different investment scenarios. Because of its importance, below is a brief overview of travel demand modeling and its relationship to the BCA.

In order to plan for future transportation needs, regional transportation planners typically use a four-step travel demand model to estimate future volumes of trips on the transportation network. The four steps are trip generation, trip distribution, mode choice and network assignment. These four steps predict where trips will be coming from, where they will be going, what kind or transportation they will use, and what specific route they will use.

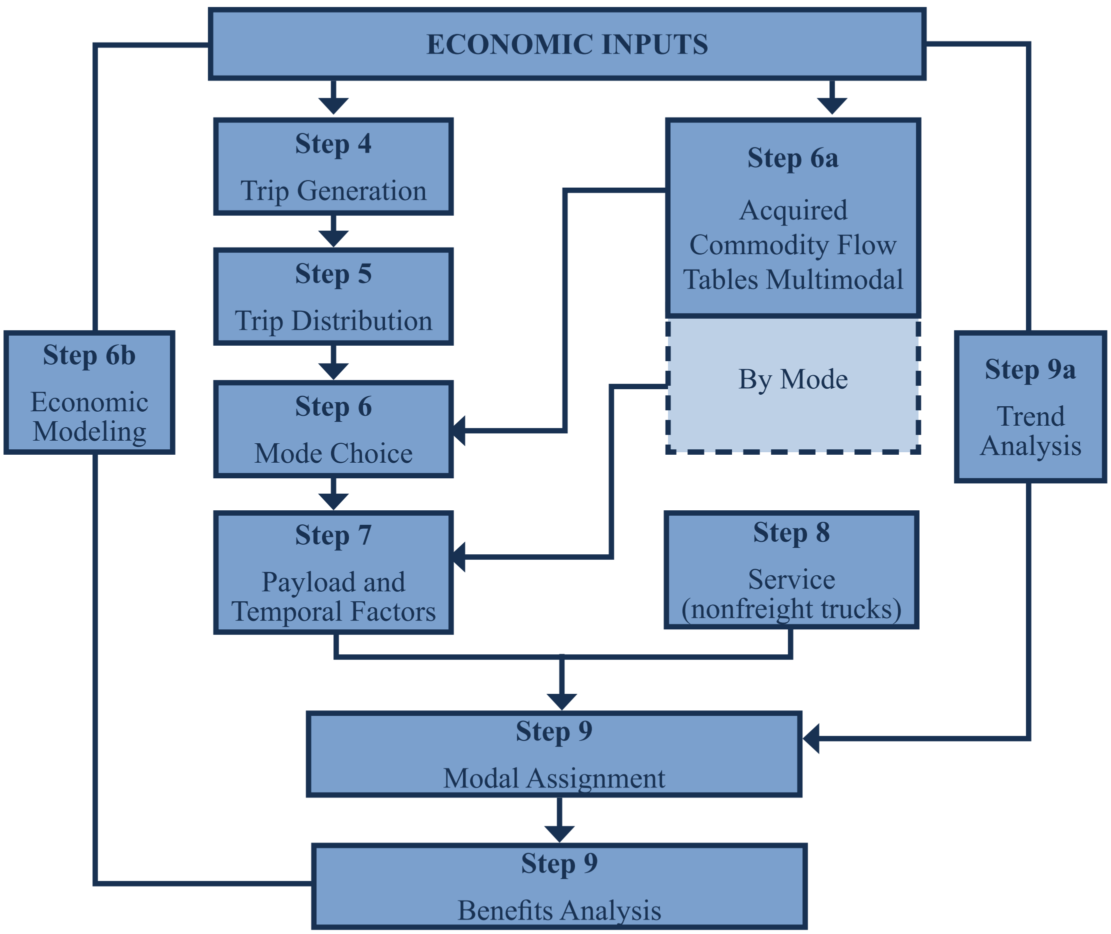
In the trip generation phase, planners estimate how many trips originate in each traffic analysis zone using data on the demographic characteristics of the population. For freight trips, surveys, models, and economic data can be used to forecast truck trip or freight generation, although acquiring this data may require significant effort.

Figure 1 below shows different approaches to incorporating freight trucks into transportation demand modeling. Our focus here is on modeling at the State or regional scale, since these scales are most typically associated with using travel demand models to estimate the benefits of specific projects. The approaches include estimating a commodity freight table synthetically (step 4),

12 The US government does not endorse any specific software or tools.

using acquired commodity flow tables (step 6a), using a separate service truck model (step 8), or using economic modeling approaches that use economic or land-use activities as exogenous variables to estimate freight flows (step 6b). Each of these approaches to estimating freight movement or truck trips would serve as inputs into different places in the four-step modeling process. *NCFRP Report 8 – Freight Demand Modeling to Support Public-Sector Decision Making*[13] provides more context for the overall framework and each of these approaches, as well as additional detail on other models.

Figure 1. Diagram. Freight demand modeling approaches to support benefit cost analysis.[14]



A number of the approaches discussed above bypass some of the steps of the traditional four-step model. When planners use a synthetic freight table, the remaining steps will occur (distribution, mode choice, assignment). In the freight distribution phase of the four-step process, the model estimates the distribution of freight flow ends. Based on distance and industry employment (or in some cases land use characteristics), the travel demand model estimates what percent of

13 This report is available at http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_008.pdf.

14 Cambridge Systematics and GeoStats LLP, NCFRP Report 8: Freight Demand Modeling to Support Public Sector Decision Making, National Cooperative Freight Research Program (Washington, DC: TRB 2010). Available at: http://www.trb.org/Main/Blurbs/164409.aspx.

freight moves in each zone will be attracted to other zones. Although there are other methods, the distribution phase typically relies on a gravity model, which is a statistical model that estimates the geographic areas that will attract freight and how much they will attract. As noted in *NCFRP Report 8 – Freight Demand Modeling to Support Public-Sector Decision Making*:

> *In the gravity model for freight, as in other transportation applications, the mathematical equations used are applied separately for flows with similar behavior (e.g., commodities).The productions and attractions by commodity are distributed in the gravity model based on the accessibility between the zones, as measured by the impedance between zones. For freight models, the impedance variable for the large geographies considered by freight is most often found to be distance. By examining the commodity flow survey data, it is possible to determine those parameters, such as the average trip length by commodity, which are used to vary the accessibility in response to changes in the impedance variable.*[15]

The mode choice phase of the model estimates which mode (highway, rail, other) that freight will use in moving between different traffic zones. Mode choice for freight depends on the characteristics of the mode, commodities, production zone, and attraction zone. Data sources such as the Commodity Flow Survey (CFS) can be used to estimate State mode choice models, but these models will be less accurate at the regional level where access to intermodal transport options may differ. Where insufficient data exists to properly model this choice, the future choice of mode can be assumed to be the same as the existing choice of mode. The Freight Analysis Framework (FAF) can be used to estimate changes in mode share in the future due to changes in the mix of commodities. For truck freight, tonnage flows need to be converted into truck trips using estimates of payload and temporal factors. Since medium- and heavy-duty trucks take up more roadway capacity than passenger vehicles, truck trips need to be converted into passenger equivalent trips.

The final phase of the model, network assignment, assigns each trip to a particular network route (Step 9 above). The truck origin-destination trip tables are combined with passenger trips before being assigned to the transportation network. Travel demand models can assign all of these trips to the network to estimate the routing of trips, changes in congestion, delay, and vehicle operating costs. These changes in system performance then serve as the inputs to a BCA to analyze freight transportation system improvements.

For both auto and truck trips, the model takes into account how congested each link in the road network will be. The model may divert traffic to less congested segments if high traffic volumes on particular segments cause congestion.

The four-step modeling process provides forecasts of travel activity that are important to determining the costs and benefits of a transportation improvement. Travel demand modeling provides forecasts of the number of trips occurring on the transportation system. This determines the universe of trips that might benefit from a specific improvement.

15 Cambridge Systematics and GeoStats LLP, NCFRP Report 8 – Freight Demand Modeling to Support Public-Sector Decision Making, National Cooperative Freight Research Program (Washington, DC: TRB, 2010), p. 52. Available at: *http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_008.pdf*.

The model also takes into account the dynamic nature of travel demand. One can use a travel demand model to determine the level of demand for a roadway with or without an investment that improves the roadway. A transportation improvement may cause users to divert to improved roadway segments. Travel demand modeling seeks to estimate the volume of traffic that will be diverted. Traffic diversion may reduce the benefits of the transportation improvement to existing users, but it will also create benefits for users on other segments of the transportation network.

Travel demand modeling may also seek to estimate the changes in travel behavior caused by a transportation improvement. For instance, a roadway improvement may create additional trips or move trips into peak traffic hours if the investment reduces congestion. Travel demand modeling can estimate the effects of these behavior changes on the benefits of a transportation project.

The outputs of the four-step travel demand modeling process provide some of the inputs to a BCA. Travel demand models can estimate travel speed, delay, transit time, and traffic volumes on a transportation network. This can be done with and without a planned transportation improvement, providing data on a baseline and alternative transportation scenario.

It is important to note that travel demand models do not typically allow the user to separate passenger and truck trips after they have been assigned to the network. As such, a planner must make assumptions on how the overall changes in congestion and transit time measured by the model would apply to freight trucks.

Traditional four-step travel demand models have several additional limitations. Freight trip making is driven by a variety of factors that are not typically captured. For instance, the number of truck trips is determined in part by complex logistical decisions – the use of inventory, the frequency of shipments, the choice of equipment type, the average payload carried, vehicle repositioning, empty mileage, the location of warehouses, the choice of less-than-truckload or truckload shipments, vehicle routing choices, and other factors. More sophisticated models need to be used to more fully capture transportation and logistics decisions. Some of these microsimulation and agent-based models are briefly described below.

Other limitations of using traditional transportation demand models for freight is that they may not incorporate appropriate constraints for truck routes, time of day operating patterns, or geometric limitations for truck operations, nor may they reflect appropriate seasonality patterns in shipment deliveries.

It is also important to note that the four-step travel demand models typically only incorporate direct user benefits into their calculations. Broader secondary impacts or benefits derived from productivity improvements would require additional analysis techniques to estimate (discussed below).

Microsimulation Models and Agent Based Models

The traditional four-step modeling approach has difficulty capturing the factors that influence shipper and carrier behavior. Although more common for forecasting passenger travel demand, examples of freight behavioral modeling remain relatively limited. Microsimulation models represent the individual movement of large numbers of shipments and their attributes. Agent-based modeling defines potential actors in freight transportation. Each actor has an allowable set of actions and interactions. These models allow planners to perform "what-if" analyses and develop scenarios to understand the behavior of the freight system. More complex models can capture multi-stop freight delivery routes and represent more complex logistics, such as the movement of goods from warehouses and distribution facilities. As an example, larger transportation planning agencies in New York and Chicago have invested in these models. The Freight Activity Micro-simulation Estimator (FAME) is an example of a modeling framework that incorporates behavioral elements that can capture more complex logistics.[16]

FAME includes five modules to more accurately characterize freight transportation and logistics decisions:

- The first module recognizes all the firms in the study area and identifies their basic characteristics.
- The second module determines the types and amounts of incoming and outgoing goods based on each firm's characteristics and replicates their supply chain designs.
- The third module defines shipment sizes based on the previously collected data about the firms' characteristics and the way they trade commodities with each other.
- The fourth module makes decisions regarding shipping mode, haul time, shipping cost, warehousing, etc.
- The fifth module investigates the impacts of the movement of goods on the transportation network.

Regardless of how transportation impacts are estimated, the BCA translates the transportation impacts of various project alternatives into monetary impacts. The BCA provides a methodology for comparing projects with differing cost structures and benefit streams over time. It translates the impacts of these projects into net-present-value estimates and benefit-cost ratios that can be used to assess these projects both relative to a baseline case and against each other.

4.1.2. Purpose of Benefit Cost Analysis

A BCA has three primary functions. First, it can be used to evaluate whether a project should be undertaken. It can answer the question "Will the benefits of a project exceed its costs?"

It can also be used to determine when a project should be undertaken. For instance, if a project is not currently beneficial, will traffic growth make conducting a project economical at a future date?

Lastly, the BCA can be used to identify which alternative should be funded. In many cases there are numerous projects that could be conducted to improve the transportation system. BCA can be used to answer the questions "Which alternative will yield the most net benefits?" and "How does a specific project compare to other projects that could be undertaken?"

16 K. Kawamura, et al. Development of a Freight Policy Analysis Tool for Northeastern Illinois and the United States: Freight Activity Microsimulation Estimator. Urban Transportation Center (Chicago: University of Illinois at Chicago, December 2011). Available at: *http://www.idot.illinois.gov/assets/uploads/files/transportation-system/reports/dpit/final%20report%20freight%20activity%20microsimulation%20estimator%20%28fame%29.pdf*.

4.1.3. Components of Benefit Cost Analysis

The major components of a benefit cost analysis (BCA) include the following: establish objectives, specify assumptions, define a base case and alternatives, analyze traffic effects, estimate benefits and costs relative to the base case, compare net benefits, rank the alternatives and make recommendations. Each of these is addressed in more detail below.

The first step in a BCA is to establish the objectives of the project. Objectives might include reducing congestion (by eliminating a truck freight bottleneck for instance), improving connectivity (by investing in a freight intermodal connector), or improving safety (by enhancing roadway geometric design to facilitate heavy-duty trucks). By clearly defining the objective, the number of project alternatives considered can be reduced.

Benefit Cost Analysis – a Long and Wide View

"Benefit cost analysis is a practical way of assessing the desirability of projects, where it is important to take a long view (in the sense of looking at repercussions in the further, as well as the nearer future) and a wide view (in the sense of allowing for side-effects of many kinds on many persons, industries, regions, etc.), i.e., it implies the enumeration and evaluation of all relevant costs and benefits"

— Ken Button, Benefit/Cost Analysis for Transportation Infrastructure: A Practitioner's Workshop, Workshop Proceedings, August 2010

Any BCA analysis will also rely on a set of assumptions. These would include assumptions about expected future traffic growth in the region over the life of the project and the likely composition of the future vehicle fleet. Forecasting future freight flows is more complex than passenger trips since freight movements are determined by global supply chains that are constantly shifting. Often a significant portion of freight traffic takes the form of external trips that are generated by production and consumption decisions occurring outside the region being studied. In addition, many truck carriers operate trucks that are registered outside of the region, making it more difficult to characterize the on-road fleet. The assumptions for a BCA might also include natural, legal or policy constraints on what projects can feasibly be undertaken.

Based on the objectives and the assumptions identified, a BCA analysis develops a set of alternatives to be assessed. Typically a baseline alternative that involves not undertaking an improvement (apart from providing routine maintenance) is identified. A set of alternative transportation improvements that could be undertaken are also specified and compared to the baseline. Improvements to the base case could include a rehabilitation or reconstruction of the existing facility to support heavier vehicles, the replacement of current infrastructure with a higher volume facility, or the addition of capacity to relieve congestion, such as or the addition of a truck climbing lane. Investments in eliminating impediments to the operation of heavy vehicles such as bridge clearances or turning radius restrictions could be studied. Improvements might also include operational investments, such as signal timing, weigh-in-motion technology, or other automated enforcement equipment that enhance the throughput of existing facilities.

In order for alternatives to be compared on a level playing field, the costs and benefits of each alternative (relative to the base case) need to be compared over their full lifecycle. A multiyear analysis period for comparing the costs and benefits of alternatives is established. Ideally, this analysis period should be long enough to incorporate a major rehabilitation activity for each of the alternatives.

Steps in a Benefit Cost Analysis

1. *Establish objectives.*
2. *Specify assumptions.*
3. *Define a base case & alternatives.*
4. *Analyze traffic effects.*
5. *Estimate benefits and costs relative to base case.*
6. *Compare net benefits and rank alternatives.*
7. *Make recommendations.*

The level of effort expended on a particular BCA should be proportional to the size and importance of the project. When a project is expected to generate significant benefits or have a major impact on relieving congestion, a BCA should explicitly analyze the traffic effects of the facility. Major improvements in transportation facilities can be expected to create substantial new demand, and a comprehensive BCA analysis should consider the effects of this new demand. Changes in future traffic volumes can be expected to alter the costs and benefits of the project.

The costs and benefits of an alternative are measured against the base case. Construction costs, delay costs, transit time benefits, crash costs, vehicle operating costs, emissions costs and others are measured by year and converted into a dollar value. The cost of delay to heavy-duty trucks is higher on average than other vehicles. The Federal Highway Administration (FHWA) uses $31.44 per hour for the average cost of delay for a five-axle combination truck while a medium auto has a delay cost of $16.92.[17] The American Trucking Research Institute estimates the average cost of truck delay to be higher at $65.29. These estimated costs include the direct cost of operating the vehicle. Research on trucking has shown that shippers and carriers can value transit time as high as $200 per hour, depending on the product being carried. The value of reliability (i.e., the cost of unexpected delay) for trucks is another 50 to 250 percent higher still.[18] A BCA considers an array of benefits and costs. Agency costs include design and engineering for a project as well as land acquisition and construction costs. Multi-year costs such as maintenance are also included. The construction of a project can also impose user costs as well. For instance, work zones can cause delay or increase vehicle operating costs during construction. In addition, crash risk may be elevated in work zones.

User costs and benefits include changes in travel time, delay and reliability. Reliability is often measured as the variance around either the transit time or average delay time.[19] Truck carriers and shippers can build time into their delivery and ordering schedules to account for delays caused by recurrent congestion (such as rush hour delays). Unexpected delays caused by non-recurrent congestion are more costly. The value of reliability can be difficult to estimate for

17 Federal Highway Administration, Report to Congress – 2013 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance, "Appendix A. Highway Investment Methodology – Valuation of Travel Time Savings." Available at: *http://www.fhwa.dot.gov/policy/2013cpr/appendixa.htm#13*.

18 Federal Highway Administration, Freight Transportation Improvements and the Economy, FHWA-HOP-04-005 (Washington, DC: FHWA, 2004). Available at: *http://ops.fhwa.dot.gov/freight/freight_analysis/improve_econ/*.

19 There are different approaches to measuring reliability including the 90th and 95th percentile travel time, travel time index, buffer index and the planning index. The 90th or 95th percentile travel time estimates how bad delay will be during the heaviest traffic days. "The travel time index is the ratio of a measured travel time during congestion to the time required to make the same trip at free-flow speeds. The buffer Index represents the extra buffer time (or time cushion) that most travelers add to their average travel time when planning trips to ensure on-time arrival. The planning time index represents the total travel time that should be planned when an adequate buffer time is included. The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay."

truck freight, since different types of commodities may have significantly different costs of delay associated with them. A manufacturing customer using a just-in-time delivery system may need to shut down their operations if they exhaust the supplies that are available for production. These types of shipments could incur very large delay costs. Shipments that are less time sensitive might have much lower delay costs associated with them. Unexpected delay costs have been estimated to be between 50 percent and 870 percent the value of truck delay time.[20]

Increases in crashes are also user costs. Typically travel time improvements create most of the benefits associated with a transportation investment. Travel time improvements are typically monetized using data on the average salary and overhead costs of workers. The Federal Highway Association (FHWA) has recommended using an average value of $25.75 for truck drivers in Federal BCAs, and personal travel time is typically valued at 50 percent of the per hour median household income in the region. FHWA has recommended values for use in Federal Transportation Investment Generating Economic Recovery (TIGER) Grant applications that are broken down between personal and business travel, and estimated separately for local and intercity travel. For instance, they estimate that local personal travel time is valued at $12.42 per hour for surface transport.[21] Projects to improve freight movement can have significant non-freight related benefits. For instance, an investment in an important highway freight corridor will also incur significant benefits from savings in passenger travel time as well.

Crash costs can be estimated using data on how much individuals are willing to pay to reduce their risk of an injury or a fatality. Default values for many of these parameters are available from a number of guidance documents discussed below. As would be expected, truck crashes tend to incur more costs due to the greater likelihood of severe injuries or death. FHWA uses $9,200,000 as the estimate of the value of a life. The TIGER Benefit-Cost Analysis Resource Guide provides estimates to value crash injuries of different severity levels.[22] Externalities, or costs to non-users, are also considered by BCAs. Externalities are uncompensated impacts that are created by users of the system but that fall on others. Emissions, noise, and other environmental impacts typically impose costs on the public at large. Reducing the cost of externalities can be an important rational for investing in freight projects since freight contributes disproportionately to air emissions and serious crash injuries and fatalities. Trucks are a large source of air pollution in cities. Concentrated truck activity in areas that surround freight centers (e.g., ports) or freight-heavy corridors (e.g., freeways such as I-710 in Los Angeles) creates negative health effects in surrounding neighborhoods.[23] A BCA monetizes these costs and includes them in the analysis. The U.S. Department of Transportation's (USDOT) *TIGER Benefit-Cost Analysis Resource Guide* provides methodologies and data to value criteria air pollutant and carbon dioxide emissions.

20 Impact of Freight Delay to Economic Productivity. April 2014, http://tampabayfreight.com/wp-content/uploads/The-Impact-of-Freight-Delay-to-Economic-Productivity.pdf.

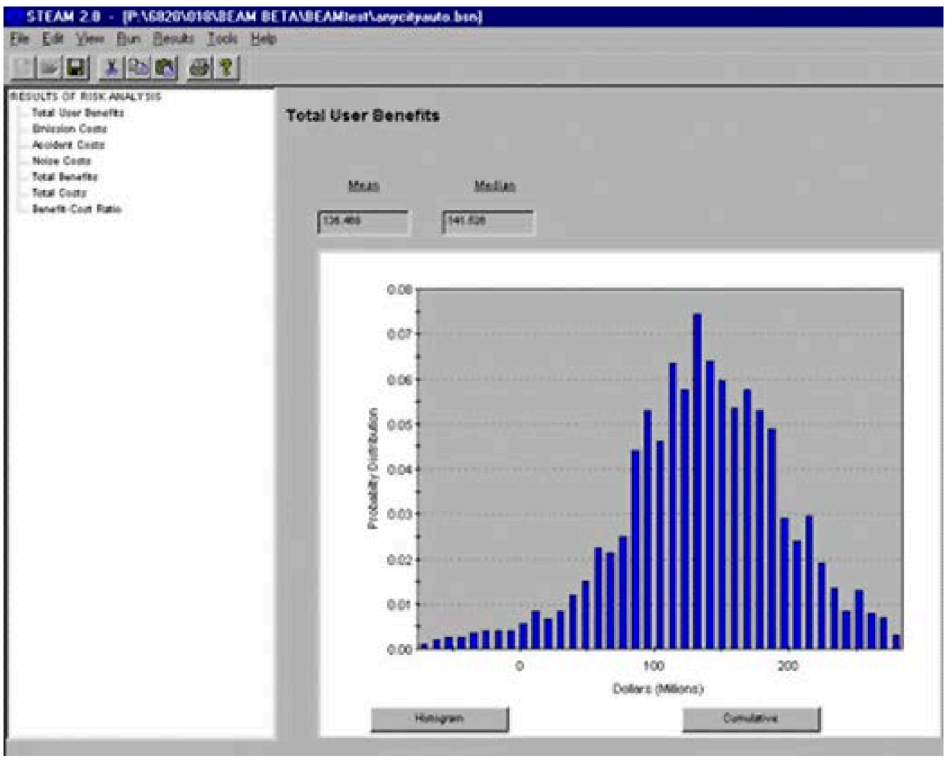
21 US Department of Transportation, TIGER Benefit-Cost Analysis Resource Guide (n.d.). Available at: http://www.dot.gov/sites/dot.gov/files/docs/TIGER%20BCA%20Resource%20Guide%202014.pdf.

22 Ibid.

23 G. Giuliano, T. O'Brien, L. Dablanc, and K. Holliday, NCFRP Report 23 – Synthesis of Freight Research in Urban Transportation Planning, National Cooperative Freight Research Program (Washington, DC: TRB, 2013). Available at: http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_023.pdf.

In a benefits cost analysis (BCA), future benefits are discounted to a present value amount. Thus multiyear cost and benefit streams are translated into a single "net present value" that provides a measure of the value of the project. When discounted benefits exceed discounted costs, a project can be considered worth pursuing. One can compare alternatives against each other according to their net present value or their ratio of benefits and costs. The project that produces the greatest net present value can be considered the most economically valuable.

BCA identifies the projects or project alternatives that produce the greatest economic value or have the greatest ratio of benefits to costs. The results of BCA can be used to recommend projects that will employ resources in the most economically efficient manner, although policy makers may face other constraints, such as budgetary considerations, that should affect the selection of a project.



Source: FHWA

Figure 2. Screenshot. Output screen from FHWA's Strategic Transportation Evaluation and Assessment Model benefit-cost analysis tool.

4.1.4. Benefit Cost Analysis Tools

A variety of software tools are available to conduct BCAs. These include MicroBENCOST, StratBENCOST, the Strategic Transportation Evaluation and Assessment Model (STEAM), BCA.Net, Highway Economic Requirements System State Version (HERS-ST), Intelligent Transportation Systems Deployment Analysis System (IDAS), GradeDec.Net and Cal-B/C. These tools allow the user to estimate the direct benefits and costs that accrue to truck operators, but do not estimate the indirect cost of congestion to freight shippers, who may incur additional inventory, production or other costs associated with the impacts of congestion on freight transit time or transit time variance. MicroBENCOST implements the American Association of State Highway and Transportation Officials' (AASHTO) guidance on conducting BCA described in *A Manual of User Benefit Analysis for Highwa*ys. The program is capable of analyzing seven categories of projects: added capacity, bypass, intersection/interchange, pavement rehabilitation, bridge, safety, and highway-railroad grade crossing. The tool requires the user to input the percent trucks and the estimated composition of the vehicle fleet. While MicroBENCOST is not a freight-specific BCA tool, it provides the capability to analyze seven categories of improvements that will benefit both trucks and autos, such as truck climbing lanes.

Although MicroBENCOST is not commonly used, it is still distributed online in 2015[24] and updated guidance for its use in Canada was made available in 2014.[25]

Surface Transportation Efficiency Model (STEAM) was developed by FHWA to estimate user benefits, costs, and externalities of transportation projects based on trip tables and networks from four-step travel demand models. STEAM calculates user benefits based on changes in consumer surplus for travelers at the link level. Figure 2 shows an output screen from STEAM. Transportation system alternatives may include up to seven modes. Peak and off-peak periods are also considered. Note that since STEAM is a post processor to travel demand models, a multi-modal transportation demand model is required to conduct multi-modal analysis. Similar to the other traditional BCA models discussed here, STEAM incorporates trucks by estimating only the direct benefits to truck operators and not the secondary benefits that may accrue to shippers.

StratBENCOST calculates benefits from time savings, vehicle operating cost reductions, accident-cost reductions, and emissions reductions. Similar to other software, benefits are calculated year by year in dollars, discounted to present value and summed.[26] StratBENCOST provides two separate models. One model can be used for network analysis and can incorporate the outputs of four-step travel demand models. The second model included in StratBENCOST can be used for single segment analysis and is for individual projects that will not have network effects. StratBENCOST incorporates cost calculations from MicroBENCOST and HERS, and provides the additional ability to consider risk and uncertainty. The benefits and costs to trucks can be incorporated by manipulating the percent trucks input. Similar to the other models discussed in this section, only the direct costs and benefits to truck operators are considered.

BCA.Net is FHWA's free, web-based tool for conducting a BCA.[27] The tool compares and evaluates alternative highway improvement projects (e.g., preservation, lane-widening, lane additions, new alignments, addition of traffic control devices, intersection upgrades). BCA.Net can evaluate multiyear, full-lifecycle investment and maintenance strategies. The model allows inputs for time-of-day distribution of traffic (e.g., peak, peak shoulder, off-peak) and traffic mix by vehicle type (e.g., auto, truck, bus). Benefits include time savings, operating cost savings, accident reductions, and air emissions reductions. BCA.NET allows the user to generate point estimates, or use risk analysis techniques to generate probabilistic results. One benefit of using

24 MicroBENCOST may be ordered from the University of Florida, McTrans Center, *http://mctrans.ce.ufl.edu/*.

25 British Columbia Ministry of Transport, MicroBENCOST Guidebook: Guidelines for the Benefit Cost Analysis of Highway Improvement Projects In British Columbia, 2014. Available at: *http://www.th.gov.bc.ca/publications/planning/Guidelines/MBC-MASTER.pdf*.

26 StratBenCost is distributed by McTrans. *http://mctrans.ce.ufl.edu/*.

27 Federal Highway Administration, BCA.Net - Highway Project Benefit - Cost Analysis System User's Manual, April 2011. Available at: *http://bca.decisiontek.com/docs/user.pdf*.

this tool for freight analysis is that it allows the user to specify with some detail the percent of trucks in the traffic mix over time.[28]

HERS-ST is a State-level version of the Highway Economic Requirements System. HERS-ST can assess transportation investments targeted at pavement, geometric or capacity deficiencies. HERS-ST can estimate the highway system performance that would result from various transportation investment funding levels. While HERS is not focused specifically on freight, the model provides different operating costs and benefits for different vehicle classes, including heavy-duty trucks that are used in freight movement.

Some BCA software is tailored to particular types of highway investment. For instance, ITS Deployment Analysis System (IDAS) is used to assess the costs and benefits of ITS improvements. GradeDec.Net is a Federal Railroad Administration model that is used to assess benefits and costs of investments in highway-rail grade crossings. For instance, it can assess upgrades, grade separation and closures to highway-rail grade crossings.

CAL-B/C is a spreadsheet benefit cost model developed by Caltrans to conduct analysis of projects in the State Transportation Improvement Program and has been used extensively in the State. The tool can prepare analyses of highway, transit, and passenger rail projects. Users input data defining the type, scope, and cost of projects. The model calculates life-cycle costs, net present values, benefit-cost ratios, internal rates of return, payback periods, annual benefits, and life-cycle benefits. While the original Cal-B/C model focused on capacity expansion projects, subsequent versions have incorporated additional project types, including transportation management systems and operational improvements. The latest revision also expands the Cal-B/C framework to include companion tools that support link and network analysis, called Cal-B/C Corridor and Cal-NET_BC.[29]

The Highway Freight Logistics Reorganization Benefits Estimation Tool is different from the traditional BCA tools described above. The tool does not replace, but rather supplements, a conventional BCA by providing an additional analysis to complement a BCA. It relies on the data collected for, and output by a traditional BCA, for its inputs. In addition, the tool requires a conventional BCA where explicit freight-associated benefits have been calculated.

The Highway Freight Logistics Reorganization Benefits Estimation Tool calculates long-run benefits to the economy additive to the user benefits typically calculated in a benefit-cost analysis resulting from a highway investment. These benefits include reduction of shipping and sourcing costs, replacement of inventory on-hand with just-in-time delivery of inputs, and wholesale reformation of the supply chain. The long-run benefits estimated result from an expansion of markets and the shift outward in the demand curve for freight transportation. The tool captures the benefits that accrue to businesses and the economy as lower freight transportation costs allow businesses to reorganize their supply chains.

The size of the long-run benefits estimated by the tool will vary with project size and freight significance. Segments with minor performance improvements in non-freight significant corridors would create few long-run benefits from logistics reorganization. Segment

28 Cambridge Systematics, NCFRP Report 12: Framework and Tools for Estimating Benefits of Specific Freight Network Investments, (Washington, DC: TRB, 2011). Available at: http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_012.pdf .

29 Caltrans, California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) User's Guide, February 2009. Available at: http://www.dot.ca.gov/hq/tpp/offices/eab/benefit_files/CalBC_User_Guide_v8.pdf .

improvements in freight significant corridors that can improve the reliability of delivery at key points would have more substantial long-run benefits. The greatest benefits would be expected where sizable networked corridor investments improve service for geographically distributed points. When investment improves transportation performance in corridors that meet the needs of diverse and numerous supply chains, large long-run benefits can occur. In these cases, logistics managers would have an incentive to adjust their supply chains, improving productivity and increasing the long-run demand for freight transportation through the corridor.

The key inputs to the Highway Freight Logistics Reorganization Benefits Estimation Tool are the baseline initial conditions, which include the project location, project length, baseline truck traffic, average effective speed, value of time, vehicle operating costs, and travel time reliability. The user also enters information on the effects of the proposed improvement, including changes in vehicle operating costs, travel time, and reliability. The user also enters the freight specific benefits from a traditional BCA. Based on these inputs, the tool estimates the reorganization benefits. This tool helps analysts using traditional BCA to incorporate the benefits that accrue from supply chain reorganization that enhances productivity. The tool is available for free on the FHWA website.[30]

Another important set of tools that can help in assessing the productivity impacts of transportation investments are those developed under the Strategic Highway Research Program (SHRP) 2 Capacity program. The SHRP 2 C11 project developed a set of spreadsheet tools to estimate the wider benefits of transportation investments. These tools are meant to be used in the "middle-stage" of project development, where a full blown analysis does not need to be conducted, but sketch planning is used to develop an improved understanding of what the magnitude of benefits for investment might be. The SHRP2 C11 tools "shift the focus of analysis from traditional transportation impact measures (i.e., travel time, cost, and safety) to broader factors that also matter to individual business operators and thus actually 'drive' economic development processes (i.e., travel time reliability, intermodal connectivity, and market access)."[31]

SHRP 2 C11 Reliability Tool – Improved transportation reliability allows business to reduce the cost of logistics. Reducing late deliveries enables a reduction in inventories (safety stocks) and can allow more centralized warehousing and delivery processes to be put in place.[32] The reliability tool takes information on the type of highway, projected traffic volume, speed, lanes and capacity, and generates measures for travel time index, average delay, buffer time, and cost of delay. The travel time index and buffer time provide a basis to further calculate the direct economic value of improving reliability in a separate accounting spreadsheet (discussed below).

SHRP 2 C11 Accessibility Tool – Transportation improvements allow businesses to access larger supplier and customer markets. The accessibility tool measures the economic impacts of transportation improvements on market access. The accessibility tool is comprised of two market access assessment spreadsheets – one for freight and one for commuters. The first spreadsheet

30 Federal Highway Administration, Freight Benefit/Cost Study: Highway Freight Logistics Reorganization Benefits Estimation Tool Report and Documentation, FHWA-HOP-08-017 (Washington, DC: FHWA, 2008). Available at: http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/bca_logistics/index.htm.

31 Economic Development Research Group, Inc. Development of Tools for Assessing Wider Economic Benefits of Transportation, Research Report S2-C11-RW-1, SHRP 2 Capacity Research Program (Washington, DC: TRB, 2014). Available at: http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-C11-RW-1.pdf.

32 Note that the benefits measured by this tool are the same ones that are measured by the Highway Freight Logistics Reorganization Benefits Estimation Tool discussed above.

uses an effective density metric with a spatial decay factor to assess the access of a firm to buyers and suppliers. This tool can also be used to assess labor market access. The second spreadsheet uses an impedance threshold metric to assess commuter access. Both work on the same general principal. They take information on zonal population or employment as well as distance or time decay factors and then generate measures of effective market size or effective market density. This information can be used to calculate the direct economic value of improving accessibility in a separate accounting spreadsheet.

SHRP 2 C11 Connectivity Tool – Improving connectivity to alternative modes of transportation also generates economic benefits not typically captured in a traditional BCA. The connectivity tool provides a way to assess the wider connectivity benefits of highway improvements that enhance access to alternative freight and passenger intermodal facilities. For freight, the tool allows the user to assess the connectivity benefits of enhanced roadway access to rail, marine, and air intermodal facilities. The connectivity assessment tool takes information on the specific intermodal port or terminal affected by a transportation project, projected ground access volume, change in access time, and fraction of vehicles on the affected access routes that have that terminal as their destination. It then looks up information regarding the modes and destinations served by that facility, and from that data it generates a connectivity index. This index provides a basis for calculation of the direct economic value of improving connectivity in a separate accounting spreadsheet, which is described next.

SHRP 2 C11 Accounting Tool – The accounting tool converts reliability, accessibility, and connectivity measures into monetary values that can be used in a BCA or economic impact analysis. The tool estimates these benefits in a way that avoids double counting benefits. For instance, the reliability benefit is based on non-recurring congestion. Reliability benefits are estimated by multiplying the reliability ratio (value of a change in reliability)/(value of a change in travel time) by the amount of time saved. For market access, the percentage change in market scale or density is multiplied by a productivity elasticity (percentage change in productivity)/(percentage change in market access). In a similar way, for intermodal connectivity, the percentage change in the intermodal connectivity index is multiplied by the elasticity of productivity with respect to connectivity. The reliability, accessibility, and connectivity benefits estimates are additive to those estimated in a traditional BCA.

The table below summarizes many of the BCA tools available.

Table 4. Benefit-cost analysis tools.

Model	Mode	Method	Geographic Level
MicroBENCOST	Highway	BC	Corridor
StratBENCOST	Highway	BC	Corridor, Region
STEAM	Multimodal	BC	Corridor, Region
HERS-ST	Highway	BC	Corridor, State
IDAS	Highway-ITS	BC	Corridor, Region
Gradec.net	Highway – Grade Crossing	BC	Corridor
BCA.NET	Highway	B-C	Corridor

Table 4. Benefit-cost analysis tools. (cont'd.)

Model	Mode	Method	Geographic Level
CAL-B/C	Highway, Transit	BC, Lifecycle	Corridor, Region
Highway Freight Logistics Reorganization Benefits Estimation Tool	Highway – add-on	BC – Reorg. benefits	Corridor, Region
SHRP 2 C11 Reliability Tool	Highway	BC – Reliability	Corridor, Region
SHRP 2 C11 Accessibility Tool	Highway	BC – Accessibility	Corridor, Region
SHRP 2 C11 Connectivity Tool	Highway Intermodal	BC - Connectivity	Corridor, Region
SHRP 2 C11 Accounting Framework	Highway Intermodal	BC – Reliability, Accessibility, Connectivity	Corridor, Region

BC = benefit cost · HERS-ST = Highway Economic Requirements System – State · IDAS = Intelligent Transportation Systems Deployment Analysis System · STEAM = Surface Transportation Efficiency Analysis Model

4.1.5. Why Use Benefit Cost Analysis?

There are a variety of reasons why policymakers should consider the use of benefit cost analysis (BCA) in transportation planning. BCA provides a tool to systematically quantify the benefits of projects. Because the BCA process requires policymakers to examine key assumptions, it can be used to make a stronger case for needed investments.

Performing a BCA allows policymakers to reduce complex multivariable analyses to a single economic metric. Because of this, the discipline of BCA allows planners to prioritize transportation investments. It should be noted that BCA is one component of a decision-making process that should incorporate a broad range of considerations, including local issues and factors that cannot be quantified.

A BCA allows planners to implement economically efficient solutions. In many cases, the discipline of BCA may reveal potential desirable modifications to projects or alternatives that are more economical.

4.1.6. Useful Resources

There are numerous resources available to assist planners in using traditional BCAs. FHWA maintains a website with a planning toolbox. The site provides information about BCAs, free BCA software and links to other tools. The *Economic Analysis Primer* is also available on FHWA's website. This document provides an overview to BCAs, as well as other economic assessment tools. A third useful resource is *User and Non-User Benefit Analysis for Highways, 3rd Edition.* This document, also known as the "Red Book," provides AASHTO guidance on the use of BCAs. The manual is available for a small fee from AASHTO. Lastly, the *TIGER BCA Resource Guide* provides technical information and default values for monetizing benefits and costs in USDOT TIGER grant BCAs, as well as guidance on methodology.

TIGER BCA Resource Guide
http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide

FHWA Planning Toolbox: Impact Methodologies
http://www.fhwa.dot.gov/planning/toolbox/costbenefit_forecasting.htm

Economic Analysis Primer
http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm

User and Non-User Benefit Analysis for Highways, 3rd Edition, which can be purchased from AASHTO
https://bookstore.transportation.org/collection_detail.aspx?ID=65

4.2. Economic Impact Analysis

4.2.1. Purpose of Economic Impact Analysis

The purpose of economic impact analysis (EIA) is typically to forecast personal income, employment, regional property values and business impacts for a defined project, program or policy. Defining which industry sectors will benefit is critical for States or regions that seek to invest in transportation projects that will help important or emerging industries that will promote the creation of high paying jobs. Investments that improve freight transportation infrastructure are often particularly important to manufacturing industries that require reliable and low cost access to suppliers and their customer markets. Industries in the manufacturing sector typically have higher than average wages, making them a focus of economic development initiatives. Defining how economic benefits are distributed geographically is also important, since States or regions wish to make investments that will create jobs locally. It is important to note that while economic impact analyses can measure the direct and indirect monetary impacts of a project, they typically don't include some environmental and safety benefits that may also provide an important justification for a project. Nonetheless, the focus of an EIA on the contribution of a project to economic growth provides important information for policymakers who are concerned with economic development.

4.2.2. Components of Economic Impact Analysis

Define the Project

The first step in an EIA is to define the project, program or infrastructure investment to be studied and what the monetary impacts of that project are. This could include enhanced landside access to ports through investment in additional roadway capacity to reduce congestion. The direct impact of a roadway improvement would include the amount of money spent on highway construction, and any funds that might be involved in operating the roadway improvement. The impact of the investment is then compared against a no-build baseline scenario. Many economic impact analyses of transportation projects don't go any further than considering the jobs and income generated by the construction of the facility. This provides a very limited understanding of the actual economic benefits since construction impacts only represent the resource cost to society.

The benefits of improvements to the transportation system can provide much greater economic impacts in some regions. We discuss approaches to incorporating transportation system improvements into an economic analysis below in a separate section. Reducing the time and cost associated with moving freight enhances the productivity of industry by allowing the same amount of goods to be produced at less cost. In brief, transit time improvements for business travelers and freight transport can be monetized and identified as a monetary stimulus for particular industry sectors. Transit time improvements for personal travel do not have the same type of direct monetary cost to consumers. Personal travel time is not considered a direct cost for any sector. Because of this, transit time improvements for personal travel are not considered to have a stimulative monetary impact in an economic impact analysis (EIA). Travel time savings for freight can be estimated based on estimates of the hourly costs of operating a truck.

Travel time savings can be capitalized into higher rents, affecting property values. Economic impact analyses conducted with traditional input-output models discussed in this section do not cover dynamic impacts over time, such as changes in property values, the reorganization of supply chains in response to lower transportation costs or other industry reorganization that may occur to take advantage of changes in input costs. These require dynamic economic models (e.g., Regional Economic Models, Inc. (REMI), TREDIS) that are discussed in the next section.

Define the Study Area

The definition of the study area is an important consideration in conducting an economic analysis. A transportation investment may be considered to have different costs and benefits at different geographical levels. A given transportation improvement might allow both new business expansion and also attract jobs and business from other regions. An EIA with a study area defined at the local level would include both of these impacts as benefits. A State level analysis would not count jobs moved from one locality in the State to another as a net gain in jobs. Expanding the geographic area in which the analysis is conducted would incorporate more spillover benefits caused by spending that leaks out of the local region – purchases from businesses outside of the local project area, but located within the State. The boundaries of a study region may be based on the jurisdictional boundaries of the sponsoring agency or the region where the project is likely to have a direct or significant impact. For some freight infrastructure projects, particularly for important freight hubs that affect international supply chains, there may be large national or global benefits that could dwarf the economic benefits at a local level. Expanding the size of the study region could be important in these cases.

Estimate Indirect and Induced Impacts

The direct monetary impacts of a specific project or investment are translated into indirect and induced impacts using an economic model. Impact Analysis for Planning (IMPLAN) and Regional Input-Output Modeling System (RIMS-II) are the two primary models that can be used. (Dynamic models REMI and TREDIS are discussed separately in the next section).[33] Based

33 The REMI and TREDIS models are also based on input-output tables, and produce estimates of indirect and induced impacts. These models are discussed separately in the next section since they also utilize a more complex and dynamic modeling approach that also allows the user to estimate productivity impacts on the economy.

Three Types of Benefits Measured In Economic Impact Analysis

Economic impact analysis deals with three types of impacts: direct, indirect and induced impacts.

1. *Direct impacts are the impact created by the money from the defined activity entering the economy.*
2. *The indirect impacts are determined by the amount of the direct effect spent within the study region on supplies, services, labor, and taxes. It includes business purchases from other businesses.*
3. *Induced impacts represents the economic activity and jobs created in all local industries due to consumers' consumption expenditures arising from the new household incomes that are generated by the direct and indirect effects of the final demand changes.*

Total economic impacts are equal to the summation of direct effects, indirect effects and induced effects.

on the goals and type of analysis, one of these models could be selected. The attributes of each of these models is discussed further below.

Both RIMS-II and IMPLAN describe the national, State, or local economy as a matrix of industry sectors. This matrix shows how the output of one industry becomes the input of another industry. As such, a dollar spent in one industry will create additional demand in other industries. These models are customized by region, and describe whether dollars spent will create local demand in a region or whether this additional demand will leak out of the region as money is spent on products made elsewhere. For instance, asphalt might be shipped from another part of the country, or engineering services provided by a company in another State. Customized tables can be purchased for counties, collections of counties, or States that show the industry multipliers for each region. Multipliers include economic output multipliers and jobs multipliers that show how indirect and induced impacts magnify the impact of direct spending in a local region.

Direct impacts would include the money entering the economy from a defined economic activity. For instance, a road construction project would involve spending money to hire engineers, construction contractors, or asphalt.[34] Other direct impacts of transportation projects, such as reduced transit time for freight trucks, can be estimated and included in the analysis. (Discussed in Section 4.2.3 below.) Indirect and induced impacts are commonly called "multiplier effects" since the direct monetary purchases associated with the project spur additional impacts that multiply the monetary effect of the original project expenditures. Indirect effects are caused by industries purchasing goods and services from other industries. The direct expenditure of dollars for a construction contract creates additional demand when a construction company purchases a bulldozer, fuel or spends money on a business service.

Induced impacts represent the additional demand arising from the new household incomes that are generated by the direct and indirect effects of spending in the economy. Because of direct

34 Note that many EIAs may treat a project's construction cost as a stimulus and ignore the reality that the funds used to build the project may reduce government spending elsewhere or be taxed away from consumers and suppress spending by households in other areas of the economy. This can be accounted for by reducing expenditures from these other sectors.

and indirect impacts, there are wages being paid to new workers, and these workers spend their incomes on food, housing, new cars, trips to restaurants or anything else. These expenditures affect output and jobs. Indirect and induced impacts are iterated throughout the economy, creating a multiplier effect that distributes economic activity.

Determine which Measures of Economic Impact Should Be Used

An economic impact analysis produces a number of different measures of economic growth. There are strengths and weaknesses to using each of these measures. Policymakers may wish to communicate the results of their analysis using different measures depending on the nature of the project being evaluated, the goals of the study and the audience they are communicating with. Potential measures of economic impact that can be used include total employment, aggregate personal income, value added and business output. It is important to note that these measures are not additive, but rather reflect different ways to measure the same economic impact. Total employment generated in a region is an easily understood statistic that policymakers are keenly aware of. One limitation of this measure is that it doesn't account for the quality of the jobs created. Aggregate personal income generated accounts for the income generated by new jobs as well as pay increases for the existing workforce. This measure underestimates the total benefits of a project since it does not include business profits paid out to local owners or reinvested in the economy. Value added (or gross regional product) is a more inclusive measure of total income and includes both corporate profit and wage income generated in the study area. Value added subtracts business inputs (purchased from suppliers) from business outputs (sales revenue) to estimate the economic activity occurring. Value added may overestimate the regional impact since some corporate profit is paid in dividends to stock or business owners that reside outside of the region.[35] Business output (which is the same as business sales or revenue) is the broadest measure of economic activity. This measure does not distinguish between businesses that have substantial local operations and businesses that generate output by reselling products made elsewhere. Note that the net value of all these measures, after eliminating double-counts and subtracting transfers, should be close to (and not additive to) the original direct net benefits of the project as measured using BCA. Incremental industry productivity benefits due to reliability, market access, and intermodal connectivity, which may occur due to reorganization of logistics, require additional analytical methods to estimate. The SHRP 2 C11 Tools (discussed in section 4.1.4 above) can be used to estimate these additional measures of productivity benefit to the economy.

4.2.3. Incorporating Transportation System Improvements into Economic Impact Analyses

Many EIAs for transportation projects estimate the economic output and jobs gains associated with the construction of the project and stop there. A transportation system improvement will obviously create greater impacts due to reductions in travel time and reliability. Representing these impacts in IMPLAN is not straightforward, but can be accomplished using the following general methodological approach.

35 G. Weisbrod and B. Weisbrod, Measuring the Economic Impacts of Projects and Programs, (Boston: Economic Development Research Group, 1997). Available at: http://www.edrgroup.com/images/stories/Transportation/econ-impact-primer.pdf.

1) **Estimate improvements in system performance** - Travel demand modeling can be used to estimate and forecast traffic volumes, congestion, and delay under different investment scenarios. Typically freight truck trip tables are estimated separately, combined with passenger trips, and assigned to the network to estimate changes in congestion and travel time for all vehicles. Assumptions about how overall changes in travel time apply to trucks are often required. (As discussed in Section 4.11).

2) **Estimate which industries benefit** - Data on major commodities shipped by truck (from the Freight Analysis Framework or other data sources) can be linked to the major economic sectors that are responsible for producing this freight. Based on this data, the monetary value of travel time improvements for each industry sector can be estimated. It may be necessary to use the transportation satellite accounts to gain a complete picture of industries transportation and logistics costs (discussed further below).

3) **Represent travel savings in the EIA model** - The way in which travel time improvement benefits will be used by each industry then needs to be represented. For instance, the industry may keep it as profit, pass it on to consumers or reinvest it in the industry. Depending on these choices, each shipper industry sector can be stimulated in different ways by the dollar value saved from reduced transportation cost.

The approach highlighted above is one that is incorporated in the TREDIS model. Freight transportation improvements could also have additional benefits from improved efficiency in their overall supply chain, including inventory cost reductions. We discuss approaches for including these dynamic effects in later sections as well.

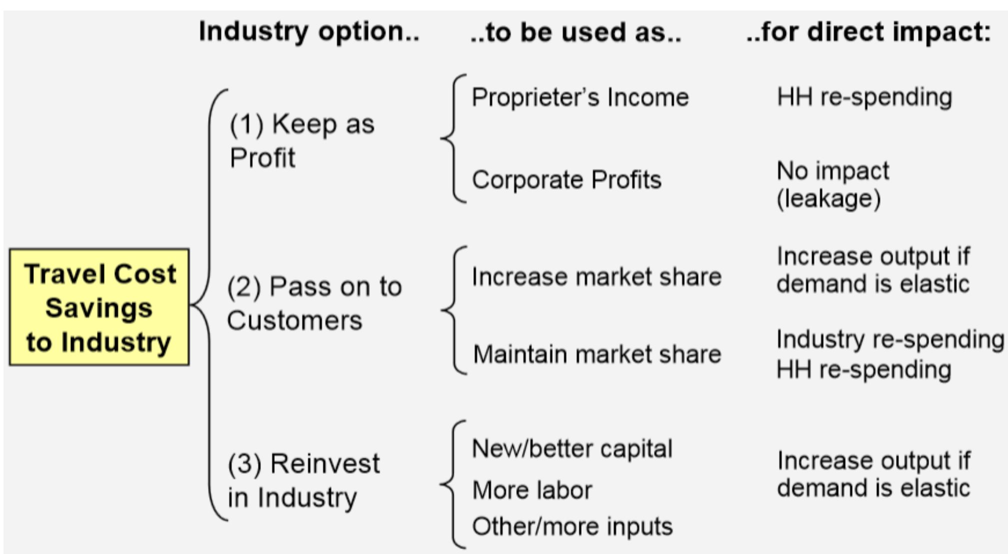


Figure 3. Diagram. Representing the benefits of travel time improvements to industry.[36]

36 Brian B. Alstadt & Glen Weisbrod, "Unlocking the Potential of IMPLAN for Transport Impact Analysis," Presented at the 7th Biennial IMPLAN User's Conference, June 2008.

Transportation Satellite Accounts

One way to apportion transportation benefits to industry sectors is to allocate them based on the tons of freight moved by commodity (discussed above). Alternatively, the transportation travel time savings can be allocated according to industry spending on truck transportation. This would have the advantage of accounting for the fact that some industries utilize smaller shipment sizes to achieve just-in-time inventory management and thus use more transportation services in terms of dollars per ton.

One can estimate transportation spending for external truck carriers by industry from the input-output accounts. One issue that analysts must deal with in conducting an economic analysis of freight transport is how transportation is represented in economic models. Input-output accounts describe how much industries buy from each other, but in the case of private fleets and other logistics functions, many shippers maintain control over these operations in-house and do not purchase them externally from carriers. Deriving a good understanding of how much is spent by shippers on transportation and logistics costs thus becomes an important step to understanding the economic impact of transportation improvements. The transportation user benefits for specific shipping industries can be estimated using the Transportation Satellite Accounts (TSA) data, from the U.S. Bureau of Economic Analysis. These data provide measures of spending by mode per dollar of output.

By multiplying the TSA share by the total output for an industry in an area, an estimate of the total spending by mode by industry can be derived. This can be used to apportion total cost savings from transportation improvements (shorter freight transit time, etc.) to individual shipping industries. Estimates of transportation savings by industry are then entered into an economic model to estimate direct and indirect effects on employment and output for freight users and their suppliers, including those that provide transportation services.[37]

4.2.4. Economic Impact Analysis Tools

The two most widely used economic impact analysis tools are:

- RIMS-II – Provides a spreadsheet tool with regional input-output multipliers, which account for inter-industry relationships within regions, also available from BEA.
- IMPLAN Model – A more complex model that provides detailed industry information for 440 sectors roughly aligned with 4-digit North American Industry Classification System (NAICS) industry codes and is available from MIG Inc.

Both of these are described below in more detail.

RIMS II

The RIMS II program provides spreadsheets of multipliers, customized by regions, that analysts can use for EIAs. RIMS II input-output multipliers show how the direct effects of local demand affect total gross output, value added, earnings, and employment in a given region.

At this writing, multipliers may be ordered for any region that consists of one or more contiguous

37 Note that most economic models normally rely on the BEA input-output accounts, which allocate transportation costs among industries differently from the TSA.

counties at a cost of $275 per region.[38] For each region that you purchase, you obtain Type I and Type II final-demand and direct-effect multipliers for all the RIMS II industries in the region. State-level multipliers can be purchased for $75 per industry. There are two options for obtaining industry detail. Analysts can receive more current data with less industry detail or get access to much more industry sector detail but with less current data.

- **Annual series.** These multipliers are available for 62 aggregated industries (in PDF format). Multipliers from this series are based on more current but less detailed national annual input-output data.

- **Benchmark series.** These multipliers are available for 406 detailed industries and for the same 62 aggregated industries that are provided in the annual series. Multipliers from this series are based on more detailed but less current national benchmark input-output data.

RIMS-II provides a transparent and low cost access to economic impact analysis data. One drawback is that because data is contained in spreadsheets, there is no software user interface to assist one in conducting the analysis.

In 2015 the Bureau of Economic Analysis plans to release a modified economic model to replace the original RIMS II. Much like RIMS II, the modified model will produce regional "multipliers" that can be used in economic impact studies to estimate the total economic impact of a project on a region. However, the modified model will be updated with new input-output data only for benchmark years (years ending in 2 and 7). The modified model will become available to customers in 2015 and incorporate 2007 benchmark input-output data and 2013 regional economic data.[39]

The RIMS II multipliers can indicate how an increase or decrease in the activity of a given industry or transportation activity (such as railroads, trucking, aviation or marine transportation) will affect jobs, income, and business sales for all other industries. For example, RIMS II could model an investment in port expansion or highway capacity. Alternatively, using the methods described above, reductions in freight transportation cost could be modelled as stimulus to all other industry sectors. One limitation of RIMS II is that it cannot by itself show how changes in market access or dynamic changes in industry in response to lower freight transport costs will generate additional productivity benefits. Capturing these effects would require the use of other tools.

IMPLAN

IMPLAN is widely used and recognized in the field of industry input-output analysis. A modified version of IMPLAN (CRIO-IMPLAN) forms the basis of the TREDIS model that is discussed later. IMPLAN is widely used for all types of analysis. Many of the recent applications for FHWA's TIGER Grant Program used IMPLAN.

The modeling framework in IMPLAN consists of two components: the descriptive model and the predictive model. The descriptive model defines the economy in the specified modeling region and includes accounting tables that trace the "flow of dollars from purchasers to producers within the region." It also includes the trade flows that describe the movement of goods and

38 Bureau of Economic Analysis, "RIMS II Online Order and Delivery System" web page. Available at: *https://www.bea.gov/regional/rims/rimsii/*.

39 Bureau of Economic Analysis, "RIMS II Online Order and Delivery System" web page. Available at: *https://www.bea.gov/regional/rims/rimsii/*.

services both within and outside of the modeling region (i.e., regional exports and imports with the outside world). In addition, it includes the Social Accounting Matrices (SAM) that traces the flow of money between institutions, such as transfer payments from governments to businesses and households, and taxes paid by households and businesses to governments. The predictive model consists of a set of “local-level multipliers” that can then be used to analyze the changes in final demand and their ripple effects throughout the local economy. These multipliers are thus coefficients that describe the response of the [local] economy to a stimulus (a change in demand or production). Three types of multipliers are used in IMPLAN: direct, indirect, and induced (as discussed above).

IMPLAN provides detailed industry information for 440 sectors roughly aligned with four-digit North American Industry Classification System (NAICS) industry codes. This level of detail allows the analysis to be more precise both in terms of the inputs (which drives the multipliers) and in the sense that the output results are at a higher granularity and thus one can better understand the sector-specific implications. Also because the sectors are matched to NAICS codes, other workforce or industry datasets can be pared easily with the findings.

Similar to RIMS II, IMPLAN multipliers can measure the direct impact of investment in a particular industry or transportation sector (investing in a port, building a highway, constructing a railroad). In addition, using the methods described above, reductions in freight transportation transit time and cost can be modelled as a stimulus to all industry sectors. Freight transportation cost reductions in trucking, rail, or other modes could be modeled in this fashion.

It should be noted that while the REMI Policy Insight Model and TREDIS models incorporate the functionality of an input-output model, they also include a dynamic simulation capability that can capture the regional inter-industry economic impacts that occur over time. These include forecast effects of future changes in business costs, prices, wages, taxes, productivity, and other aspects of business competitiveness, as well as shifts in population, employment, and housing values. Because of their ability to assess productivity impacts of transportation investments, we discuss these models separately in the next section.

While IMPLAN and RIMS II are the most common tools available for general EIAs, a number of custom models have been developed to address economic impact analysis for freight in particular regions, to incorporate land use, and to address market access or estimate the business attraction potential of transport investments.

The table below provides an overview of some of these models. We define transportation and land-use impact models as those focused on forecasting development patterns and their sensitivity to transportation conditions. Transportation and land use models integrate economic growth and input-output forecasts with more detailed spatial disaggregation of economic activity. These models can incorporate transportation networks and derive measures of access to markets and demand for locations. This provides the capability to assess the impacts on transportation projects on the location of businesses and the dispersion of residential populations. These models focus on land use forecasting, transportation access and how they affect commuting between residential and business locations. These models do not typically cover alternative modes such as rail, air, or marine and do not address specialized freight transportation requirements.

Regional impact models rely on input-output techniques to describe how specific projects will impact income, jobs and output. The models in this section are generally referred to as economic impact models. We describe some of the components separately, even though they are included as a component of other modeling systems. Market access models are discussed separately. These models seek to explain how access to transportation affects business location decisions. They measure the effects of transportation improvements on expanding labor markets, supplier and customer markets. These models can capture some of the long-run location and expansion decisions that occur as businesses respond to improved freight transportation. These models capture some effects of transportation on productivity such as economies of scale that can occur in larger markets. Some of the benefits estimated for a region are created by losses in other regions. These models don't specifically separate these productivity effects from business location effects.

Table 5. Economic impact analysis tools.

Model	Mode	Method	Geographic Level
Transportation & Land-use Impacts			
Regional Economic Impact Model for Highway Systems (REIMHS)	Highway	I-O	State, Region – applied in six States
Production Exchange Consumption Allocation System (PECAS)	Highway	I-O	State, Zones - Oregon & Ohio
Transportation Environment and Land-use Model (TELUM)	Highway	I-O	State, Zones - New Jersey
Random Utility-based Multiregional Input-Output (RUBMRIO)	Multimodal	Dynamic I-O	State, Region, Zone
Regional Impacts			
RIMS II	Multimodal	I-O	State & Region
IMpact analysis for PLANning (IMPLAN)	Multimodal	I-O	State & Region
Market Access and Impacts			
Transportation Business Attraction Model	Highway & Intermodal	Business Attraction	State & Region
Local Economic Assessment Package (LEAP)	Highway & Intermodal	I-O, Market Access, Accessibility	Region - Appalachia
Congestion Decision Support System (CDSS)	Highway	Sketch Planning Tool – includes travel elasticities	Region
University of Maryland spatial econometric model	Multimodal	Business Attraction	Zip Code

I-O = input-output.

4.2.5. Why Use Economic Impact Analyses?

Economic impact analysis (EIA) results are useful for understanding how and in what form the benefits and costs of a project will be distributed between industries both regionally and within the economy as a whole. An EIA provides policymakers and the public at large with an important way to understand how many jobs and economic output will be affected. Perhaps even more important, an EIA can tell policymakers what percent of these impacts will flow into the regional economy and what percent will accrue to other regions. For State and local policymakers, the ability to understand how benefits will affect a local region can provide an important justification for policymaking.

With freight transportation infrastructure, it has been noted that just because you build it does not mean they will come. To reap the benefits of investment in improved freight transportation, planners need to accurately characterize the potential need for the project and the demand for freight transportation. Economic growth is driven by multiple factors. Transportation is only one of many factors that create economic growth. Investments that are targeted towards regions and corridors that have growth potential will have the largest economic impacts. A well-developed economic impact analysis, supported by accurate baseline data and well developed forecasts can be used to obtain a clearer picture of what the true economic impact of a project is.

Why is Productivity and Competitiveness Important?

"Improved competitiveness refers to the enhancement of the relative economic position of one region compared to other regions. Improved competitiveness means that the relative prices of goods and services being exported from that region fall compared to the goods and services being imported into the region. The outcome is a flow of money into the region from other areas as residents buy more goods and services from the region. In ideal circumstances, the other areas also gain by being able to buy cheaper goods and services produced in the region."

– Ken Button, Benefit/Cost Analysis for Transportation Infrastructure: A Practitioner's Workshop, Workshop Proceedings, August 2010

4.2.6. Useful Resources

There are a number of useful guidebooks and references that describe the concepts, methods and tools used to conduct an economic impact analysis. Three key resources are noted below.

Cambridge Systematics, Inc., Economic Development Research Group, Inc., and Boston Logistics Group, Inc., *Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects*. August 2006.

U.S. Department of Transportation, Federal Highway Administration, *Economic Analysis Primer*. Transportation Performance Management.

Glen Weisbrod, *Measuring the Economic Impacts of Projects and Programs*, Economic Development Research Group, Burton Weisbrod, Northwestern University. http://www.edrgroup.com/images/stories/Transportation/econ-impact-primer.pdf

4.3. Dynamic Modeling Tools to Measure Productivity Impacts

4.3.1. Overview

In the preceding sections of this guide, we have shown that there are a number of tools and models available for analyzing regional economic impacts of improved performance of the transportation system and, especially, of performance of freight carriage. These tools are focused on employment, output, income, and some related metrics of economic impact. But, as discussed in the introduction, many State and Metropolitan Planning Organization (MPO) officials want to know the impacts of improved freight carriage in terms of the productivity of their region.[40] And they may want to demonstrate to other stakeholders that improved freight movement increases the productivity of the regional economy. Generally, increased productivity in a region leads to a higher standard of living in that region.

We focus in this section on models that are (a) dynamic economic models that are capable of assessing productivity and sensitive to changes in transportation time, costs and accessibility changes, (b) available for any State or sub-state region of the US and (c) available for use directly by staff of State DOTs, MPOs and their consultants. The U.S. Government does not endorse specific products, software, tools or manufacturers. Trademarks, manufacturers' names and specific products appear in this report only because they are considered essential to the objective of this document.

REMI TranSight and TREDIS are currently the two examples of models that fit all of the above criteria. They are discussed in more detail later in this report. There are also other models that fit some, but not all of these criteria. For instance, Global Insight has dynamic, State-level transportation impact models. They are not available below the State level require hiring their staff to conduct a. Another dynamic model example is the INFORUM model developed by the University of Maryland. It offers national and international trade models that have been used for several transportation studies of national economic impacts. Their STEMS model of U.S. States is top down rather than bottom up, meaning that it shares down impacts of national policies to States, and cannot assess State level impacts of State-specific programs, projects or policies. Also, the University of Maryland typically uses their staff to perform the data runs. Thus while there are a variety of companies and universities that have dynamic models, they are typically not available for MPO or sub-state levels and are typically not available for direct use by State DOT, MPO or consultant staff.

4.3.2. REMI and TREDIS

As discussed above, two models—REMI TranSight and TREDIS—have been designed to go beyond projections of increased income and employment and to estimate improvements in regional productivity. Both are available as commercial products.[41] REMI is offered

40 Unlike EIA measures (e.g., output), productivity benefits (if measured accurately) would be additive to the value measured by BCA.

41 TREDIS was also designed to be compatible with FHWA's highway benefit-cost guidelines and FAA's s aviation user benefit-cost guidelines.

by Regional Economic Models, Inc. TREDIS was created by the Economic Development Research Group (EDR). Both are designed to be used by engineers and planners who do not have training in economics. REMI users purchase licenses and download the software to their computers. TREDIS is web based and users purchase subscriptions to gain access. These models are commonly used to comprehensively address the productivity impacts of transportation investments. Note that in Section 4.1.4 above, we discuss the SHRP 2 C11 tools, which provide a way to assess the wider benefits of transportation, including some productivity impacts. The SHRP 2 C11 tools are discussed separately above since these tools are designed to be additive to other types of analyses (BCA, EIA) and do not provide comprehensive productivity metrics.

REMI and TREDIS have several key analytical features in common, and they also have significant differences. There are differences in the methodologies employed to develop the estimating equations in these two models, but these differences are of limited interest for potential users, as they do not affect the validity of the results. But there are substantial differences that are relevant for users.

In part, key differences between the two are due to the fact that they were developed for different purposes. REMI is designed as a means for evaluation of a very wide range of government policy options.[42] TREDIS is specifically designed for analyzing impacts of transportation improvements.

REMI was originally developed in 1977 to analyze government policy options for Massachusetts; it was called Massachusetts Economic Policy Analysis (MEPA). It was soon put in a more general form to be used for all States and counties. It was not developed as a specialized tool for transportation improvements. The firm, REMI, was founded to make the model available and continue its development.

REMI has often been used to analyze regional impacts of transportation improvements, especially highway improvements. But, as an all-purpose tool, it has also been used to estimate effects of air-pollution regulations, investment in a baseball park, tax incentives for businesses, other tax or subsidy measures, and many other policy choices.

After preliminary testing in Vancouver in 2006, TREDIS was launched as an available system in 2007. As noted above, it was designed expressly and solely for analysis of transportation-improvement projects.

Broadly, the difference between the two is that TREDIS has a more detailed treatment of transportation improvements and a much more detailed treatment of freight improvements. REMI, on the other hand, estimates a broader array of impacts. For example, REMI analyzes impacts of economic growth on a region's demographics, estimating increased in-migration as a result of more job openings, higher wages, and the like.

Principal common analytical features include the following.

- The core of each model is a set of equations for that can be used to estimate the economic impacts of transportation improvements and projecting them into the future. These equations are linked to an input-output table that distributes impacts across industries and traces the impact of each industry's growth on future growth in the region. Both models are dynamic.

42 As discussed below, an organization that wants to use REMI to analyze the impacts of improvements in transportation system performance must utilize a pre-processor to format the input data.

- Both models do BCA of improvements.
- Data requirements are similar in many ways, and data requirements are not onerous.
- Both allow selection of a region other than a State.
- Both track supply and price of labor and capital.
- Both explicitly treat adjustments in the supply chain in response to improved performance of freight carriage. But they do so in somewhat different ways.

> ***Productivity Impacts of Congestion in Oregon***
>
> *The Oregon Business Council and the Portland Business Alliance used TREDIS to evaluate the cost of congestion to the regional economy in terms of changes in business operations, household costs and market access, and the implications for future economic productivity, competitiveness and growth.*
>
> *—The Cost of Highway Limitations and Traffic Delay to Oregon's Economy. Prepared by Economic Development Research Group, 2007. Available at: http://portlandalliance.com/assets/2007-Congestion-Report.pdf*

- Both measure productivity increases.
- There is a potential issue in treatment of relocation effects. Both models, in somewhat different ways, allow a user to differentiate between the effect of businesses moving to a region and growth from businesses already there.

Each of these features is described further below.

The input-output table is an analytical device that is virtually unknown outside the economics profession. Standing by itself, an input-output table is not a forecasting device, but it is very useful for support of economic projections. Briefly, for any given industry, the input-output table tells what that industry must buy from each other industry to produce its own output. For example, for $100 of output value, an automobile maker might have to buy $18 worth of steel, $8 worth of electrical wires, and so forth. Expressed as percentages, these figures are known as input coefficients. Thus, when a cost reduction, or a follow-on impact, increases the demand for the product of Industry A, we know the effect on all other industries in the region. And the input-output table allows us to trace, in turn, the next round of impacts. The input-output tables in both models have very detailed breakdowns of industry sectors—70 unique industries in REMI. TREDIS has 440 industry sectors within the model but reports detailed information on 86 of them.

A dynamic model is one in which growth rates (or other key parameters) are adjusted in every future year according to the values projected for the previous year.

Benefit cost analysis, as discussed earlier in this guide, is the evaluation of a project based on direct impacts on users. This kind of analysis is based on changes in performance measures which are required for any further economic analysis of the impacts of a project.

Data required for each model are readily accessible. Broadly, two sets of data are required. One is highway travel data, current and projected—with and without the improvement—and projected changes in performance measures. These are data any department of transportation (DOT) will have. For the regional economic analysis, both models are designed to use the extensive data available from the Bureau of Economic Analysis (BEA) or the Bureau of the Census. Data from BEA include current input coefficients for input-output tables.

A region can be defined by selecting a set of counties. Thus a part of a State, or a region with parts in more than one State, can be defined for the analysis. Both allow definition by zip codes, but this is of limited value. Very little standard economic data are available below the county level.

Supply and price of labor and capital are essential elements of the productivity calculations. The amount and value of labor and capital required for future output provide the inputs needed to calculate productivity of labor and productivity of capital.

Supply chain adjustments are the critical element in the second-order responses to improvements in freight-system performance. Changes in transit times, reliability, or other measures change shippers' calculations of the optimum balance between the cost of freight transportation and inventory cost. For example, lower transport costs likely lead to longer lengths of haul and lower inventory costs as the number and location of distribution centers change. Factory-location decisions can also be affected. REMI bases the adjustment on the change in "effective distance" between points—as transit times drop, effective distance drops. TREDIS directly uses changes in transit times, or other measures, to make adjustments in the supply chain. The effective distances in REMI are highway based, so some external modifications are needed to accommodate rail or intermodal rail improvements. This latter point is discussed further as one of the differences between REMI and TREDIS.

Modeling Tools Based on the REMI Model

A number of states have created modeling frameworks based on REMI to estimate the economic benefits of freight transportation investments. These frameworks have typically started with a freight commodity flow model and a highway network model that is used to estimate highway transit time and travel cost savings for freight moved by each industry. These models also include a Transportation Business Attraction Model that allows one to estimate the market access and connectivity benefits that go beyond travel cost changes. The results of the travel demand and business attraction model are then used as inputs into the REMI model to estimate the economic impacts and productivity benefits that accrue from transportation investments in the long run. These modeling frameworks include:

- *HEAT - Highway Economic Analysis Tool – used in Montana.*
- *MCIBAS - Major Corridor Impact-Business Analysis System – applied in Indiana.*
- *BEST - Benefits Estimation System for Transportation – created for Michigan.*

Productivity is measured by the ratio of dollar value of output to input. The most widely used measure of productivity is labor productivity—dollar value of output divided by number of workers. There is a measure called total factor productivity which is supposed to capture all inputs as well as labor,[43] but estimation of TFP requires much more complex models and does not add that much for the purpose of estimating regional productivity gains from transportation improvements. Both REMI and TREDIS provide labor productivity.

Relocation effects are a general problem with all models that estimate economic growth from freight transportation improvements is the distinction, or lack of it, between growth of businesses already in the region and growth from businesses changing locations, i.e., moving into the region because of the improvements. It could be the case that reduced freight transportation costs allow a product to be sold at lower cost, expanding the market for this product. In this case, the new production might not displace any existing production. Alternatively, improved freight transportation might encourage production to be moved into the region from a location where transport costs are higher. In terms of the impact on the region, there is no difference. But it does make a difference from the national perspective. Part of the effect of firms relocating is offset by lower growth in other regions. This could matter in the case of Federal grants. Both REMI and TREDIS offer ways for separately identifying business relocations. They are somewhat different, but they address the issue, at least in part.

There are analytical issues here that may be almost impossible to address fully. When we say "relocation," we might think of a firm closing a plant or facility in one place and setting up a comparable facility in another place. But the actual case may be a firm changing a location decision for a new facility which would otherwise have been somewhere else. Example: A firm intending to build a new facility would, in the absence of a freight improvement, have built it in Region B. But, in light of the improvement, the firm chooses Region A. The same issue may arise with expansion, or not, of a facility in Region B; the firm could decide to choose to invest in a new facility in Region A rather than expand the existing one in Region B. It is difficult to know what firms' intentions were before the improvement occurred. While it may be impossible to tease out with precision exactly what firms would have done in the absence of the improvement, we can say that both REMI and TREDIS provide a methodologically rigorous way to distinguish between relocation effects and additional growth in output due to efficiency gains.

Principal analytical differences between REMI and TREDIS include:

- REMI Policy Insight requires a special pre-processor to analyze transportation improvements.
- TREDIS explicitly treats all freight modes; REMI does not.
- TREDIS breaks down freight flows by commodity and mode; REMI does not.
- REMI responds to reduced highway transit times by shrinking the "effective distances" among producing centers, supply areas, market areas, and the like. TREDIS directly reduces transit times.

43 Total-factor productivity (TFP) is a variable which accounts for effects in total output not caused by traditionally measured inputs of labor and capital. If all inputs are accounted for, then total factor productivity (TFP) can be taken as a measure of an economy's long-term technological change or technological dynamism. TFP cannot be measured directly. Instead it is a residual, which accounts for effects in total output not caused by inputs.

- REMI reports on a wider range of economic and demographic impacts. TREDIS is more narrowly focused on transportation and freight transportation and reports in greater detail in those areas.

Pre-processor requirement: For both REMI and TREDIS, the analysis starts with traffic and performance data and projections from a client agency's own data and travel model. TREDIS requires information on freight volume (tonnage, number of vehicles), economic value, mode, origin-destination, commodity mix, and/or affected industries. Estimates of the change in trips, vehicle miles of travel, and accidents for a given investment serve as inputs to the model. Based on this data, TREDIS estimates the change in operating costs by industry, changes in travel time to air, sea and rail terminals, and changes in market size.

REMI's Policy Insight, however, cannot directly use these transportation inputs to estimate economic impacts. An adjunct—in effect, another model called a "pre-processor"—is needed to convert the transportation inputs into a form that Policy Insight can work with. To meet this requirement, the firm has developed TranSight, a model that performs the required conversion. For analysis of transportation projects, the firm offers a package combining the two—sometimes referred to as "REMITranSight" or simply TranSight.

A DOT or MPO that wants to use REMI must either purchase the TranSight package or engage a consultant to develop a custom-made pre-processor. This is done occasionally. A model called the Benefits Estimation System for Transportation (BEST) was developed for Michigan DOT that combined the REMI model with a custom pre-processor several years ago.[44] The pre-processor converts output from the travel demand model, VHT and VMT for the Build/No-Build model runs, into economic variables that can be used by the REMI Model – reductions in input costs by industry sector. Other modeling frameworks that combine a pre-processor with the REMI model include the Highway Economic Analysis Tool (HEAT) in Montana[45] and the Major Corridor Impact-Business Analysis System (MCIBAS) in Indiana.[46] If the project consists of a corridor or segment, HERS outputs can be used as inputs to REMI, but it is not a simple procedure. Cambridge Systematics did this for a Wisconsin DOT study in 2003. Generally, when State DOTs or other agencies wish to use REMI to analyze a transportation project, they use the TranSight package.[47]

Freight modes: TREDIS analyzes freight movement in a much more fine-grained manner than does REMITranSight. TREDIS includes all modes of freight transport (marine, rail, air, truck) and estimates changes in travel time to air, sea and rail terminals, allowing analyses of multimodal transportation and mode shifts. TranSight is basically highway oriented and does not, for example, incorporate rail freight as a separate mode and does not separate single-unit

44 Michigan Department of Transportation, Economic Benefits of the Michigan Department of Transportation's FY 2010-2014 Highway Program, March 2010. Available at: https://www.michigan.gov/documents/mdot/MDOT_economicbenefitreport_202828_7.pdf.

45 Cambridge Systematics, "The Highway Economic Analysis Tool" web page. Available at: http://www.camsys.com/HEAT.htm.

46 John Kaliski and Glen Weisbrod, Guide to MCIBAS (Major Corridor Investment-Benefit Analysis System) and Its Economic Impact Analysis Component. April 10, 1998. Available at: http://www.edrgroup.com/pdf/mcibas-system-intro.pdf.

47 It may be the case that a state agency other than a DOT has obtained REMI Policy Insight without TranSight. Often, this would be the finance agency in a state government. It may be feasible for a state to obtain additional licenses for the DOT with the TranSight component included. Whether this would result in a cost for the DOT lower than that for getting the complete REMITranSight package separately would depend on the specifics of the existing arrangements between the state and REMI.

trucks from combination trucks. A REMI user, however, can make external adjustments to the performance characteristics of the highway mode in the model so that it would perform like intermodal rail or rail or any other freight mode. TREDIS includes air and water freight movement as well as highway and rail.

Commodity flows: TREDIS uses commodity flows based on the CFS and uses specific origin-destination flows by mode. This allows estimation of economic and productivity impacts on an industry-specific basis rather than on averages of all freight flows. Linking flows to mode allows results to reflect performance characteristics of different modes. The result is a more detailed estimate of the nature of the impacts by its 86 industry sectors and by locations and, likely, a more accurate estimate of the overall impact.

"Effective distance": Since REMI is highway based, changes in effective distance reflect changes based on highway performance characteristics. If the improvements are in another mode, users must make external adjustments to the model to cause it to reflect performance of the mode in question.

Breadth of reported impacts: Both models report on a wide range of impacts, including all the basic measures of economic impacts—employment, income, output, and related measures. REMI, for example, also estimates and takes account of government income and expenditures as it traces all effects through the regional economy. REMI also reports on future demographics—in-migration as firms' growth and rising prosperity attracts migration from other regions. This is because the theoretical underpinning of REMI is such that it seeks to estimate the regional economy in a new equilibrium following the improvements. TREDIS's concentration on transport and freight means more detail on regional labor markets and markets for final goods and intermediate goods broken down by industry and location. The finer detail can be expected to enhance the accuracy of the projected impacts.

4.3.3. Concluding Observations on REMI and TREDIS

Improvements in other regions: Both models appear to implicitly assume that transportation performance in other regions remains unchanged. In other words, system performance is improved in Region A but not in other, competing regions. Clearly, performance improvements in competing regions would offset some of the effects of improvements in Region A. This cannot be considered as a methodological fault in the models. It is a problem inherent in the task of estimating the effects of a given set of improvements in a particular region. Ordinarily, neither the users nor the model builders can be certain of what officials in a competing region might do in the future. Further, this should be a problem only for relocation effects; it should not be an issue for improved efficiency of businesses in Region A.

Need for skills in economics: As noted earlier, both models are designed to be used by planners and engineers who do not have specialized training in economics. We believe agencies using these models should exercise some caution here. They would be well served if a trained economist could assist in interpreting the outputs. When external calculations of productivity are to be carried out, this is even more important.

General Summary:[48] Both models are widely used and have met the requirements of many users in State governments, metropolitan planning organizations (MPOs), and other agencies. Each model was designed for a different purpose.

Both tools report changes in labor productivity. REMI can be used to evaluate a wide range of public policy actions and reports a somewhat wider range of impacts. TREDIS calculates productivity of capital. In both cases, further external calculations will lead to total factor productivity. TREDIS is focused solely on transportation and is more detailed in its analysis of freight improvements. This is particularly true with respect to examining modes other than trucking and examining the impacts on intermodal transportation, where it has additional capabilities for analyzing the impacts of freight transportation improvements. Specific needs and requirements of a user should be considered when determining the need for and selecting a tool.

As stated earlier, the U.S. Government does not endorse specific products, software, tools or manufacturers. Trademarks, manufacturers' names, and specific products appear in this report only because they are considered essential to the objective of the document.

4.4 Simplified Methods

This section provides some examples of simplified methods that have been employed by States or regions to estimate the economic effects of freight transportation improvements. The examples discussed below show approaches that can reduce the cost and effort involved with using complex models. Agencies that have less need for rigorous and sophisticated analyses but greater need to conduct analyses under tight deadlines using limited resources might find these methods illustrative.

4.4.1. Southeast Michigan Council of Government's Simplified Economic Analysis Tool

The Southeast Michigan Council of Government (SEMCOG) has developed the spreadsheet-based "Simplified Economic Analysis Tool" to streamline the process for conducting economic analyses for transportation projects in the SEMCOG region.[49] The tool includes an approach that is consistent with SEMCOG practices and existing tools. It leverages available resources, including the existing travel demand model for the region and the Michigan DOT's economic model. The SEMCOG Travel demand model is used to estimate changes in performance measures by county. The Simplified Economic Analysis Tool serves as a bridge between the travel demand model outputs and the economic impact analysis. The tool uses the MDOT REMI model derived estimates of elasticities to estimate industry impact by sector. These include direct, indirect and induced effects.

The tool can consider the economic impacts of freight-related and other transportation projects and describe the economic value of transportation investments. The tool can be used for evaluating transportation investment scenarios for cost effectiveness and to assist in discretionary grant applications. The Simplified Economic Analysis Tool is used to assess the user benefits and economic impacts of individual projects, groups of projects, or programs of projects that can be modeled in the SEMCOG travel demand model. The tool can be used to assess the

48 For a lengthy and very detailed discussion of these two models, some readers might want to consult "Analyzing the Economic Impacts of Transportation Projects," published in September, 2013, by the Connecticut Academy of Science and Engineering.

49 Freight & Economic Analysis Study. Talking Freight. November 14, 2012.

overall benefits of projects and prioritize the value of projects. The economic impacts are driven by work-related automobile travel and truck travel, and thus the tool can help assess projects that improve freight travel. Specifically, the tool estimates regional economic impacts, gross regional product, personal income, employment (total and by industry group), cost-effectiveness measures, benefit-cost ratios and net present value.

The screenshot below (*courtesy of SEMCOG*) shows some of the outputs of the model. As noted above and shown below, the tool provides estimates of the direct user benefits and translates these into a BCA providing benefit-cost ratios and a net present value of the project. In addition, the tool conducts an economic impact analysis, providing estimates of changes in economic output, employment and income. Other regions interested in simplified analysis may benefit from examining the approach taken by SEMCOG, although they would need to customize the tool with regional economic data to obtain results that would be valid for their area.

SEMCOG **SIMPLIFIED ECONOMIC ANALYSIS TOOL**

DIRECT USER BENEFITS (mil. 2010$)	25-Year Total	Annual Average
Travel Time Savings	$932.3	$37.3
Vehicle Operating Cost Savings	$84.0	$3.4
Safety Improvements	$0.0	$0.0
Emissions Cost Savings	-$20.1	-$0.8
TOTAL USER BENEFITS	$996.2	$39.8
BENEFIT-COST RATIO	3.3	
NET PRESENT VALUE (mil. 2010$)	$696.7	

Note: Impacts on the SEMCOG regional economy do not include short-term construction impact

IMPACTS ON SEMCOG REGIONAL ECONOMY	25-Year Total	Annual Average
Gross Regional Product (mil. 2010$)	$2,139.3	$85.6
Real Personal Income (mil. 2010$)	$2,404.6	$96.2
Employment (job-years)	16,744	670
Natural Resources, Mining & Utilities	32	1.3
Construction	1,139	45.6
Manufacturing (other than Motor Vehicles)	281	11.2
Motor Vehicles, Bodies & Parts Manuf.	22	0.9
Wholesale & Retail Trade	1,601	64.0
Transportation and Warehousing	606	24.2
Information, Finance & Real Estate	1,804	72.2
Management, Prof. Services, Education	1,569	62.8
Health Care & Social Assistance	2,595	103.8
Accomodation & Food Services	1,370	54.8
Other Services	3,260	130.4
Government	2,466	98.6

Figure 4. Screenshot. The Southeast Michigan Council of Governments Simplified Economic Analysis Tool.[50]

4.4.2. Minnesota Department of Transportation's Guidance on Benefit Cost Analyses for Transportation Projects

The Minnesota DOT has developed guidance, a spreadsheet template, and sample values that are used to streamline the performance of BCAs. The spreadsheet template serves to provide a standardized approach to planning and executing a BCA. The recommended values for some of the key analysis parameters ensure that different BCAs can be meaningfully compared to each other. The table below shows some of the recommended values from this guidance. The table below is shown as an example of how Minnesota is managing their BCA process, not as a recommendation that any agency should use specific values for any particular BCA. Note that the USDOT has provided guidance on the values that should be used in analyses to support applications for Federal TIGER grants in the *TIGER Benefit-Cost Analysis (BCA) Resource Guide* which is available on the web[51]

50 SEMCOG, Southeast Michigan Freightand Economic Analysis, SEMCOG, July 2012. http://www.semcog.org/Portals/0/Documents/Plans-For-The-Region/Transportation/Freight/AppendixERelationshipBetweenFreightTransportationInfrastructureAndEconomicDevelopment.pdf.

51 USDOT, TIGER Benefit-Cost Analysis (BCA) Resource Guide. Available at: http://www.transportation.gov/sites/dot.gov/files/docs/TIGER%20BCA%20Resource%20Guide%202014.pdf.

Table 6. Recommended standard values for use in benefit cost analysis in SFY2014.

Variables	Current Value
Real Discount Rate	2.2%
Auto- value of travel time savings per person-hour	$15.00
Truck- value of travel time savings per person-hour	$27.20
Auto- variable operating cost (dollars per mile)	$0.31
Truck- variable operating cost (dollars per mile)	$0.95
MnDOT Crash Values	Per crash
Fatal	$10,400,000
Injury Type A	$540,000
Injury Type B	$160,000
Injury Type C	$80,000
Property damage only	$3,300

MnDOT = Minnesota Department of Transportation

4.4.3. Rules of Thumb for Economic Impact Analyses

In *Measuring the Economic Impacts of Projects and Programs*, Glen and Burton Weisbrod provide the following rule of thumb for the magnitude of industry job and output multipliers for regions of different sizes:

> *Input/output models are available for county level or larger areas and provide multipliers that are estimates of local spending impacts assuming continuation of current inter-industry trade patterns and local flows of money into and out of the area. The magnitudes of these multipliers vary depending on the technology of the industry in which spending occurs and the size of the area economy – which affects the portion of these impacts that remain in the local economy and the portion that "leaks out" to outside areas. The multiplier values for most industries are generally around 2.5 - 3.5 for national impacts, 2.0 - 2.5 for State impacts and 1.5 - 2.0 for local area (large city) impacts.*

4.4.4. Transportation Project Impact Case Studies System

The Transportation Project Impact Case Studies (T-PICS) System provides a way for practitioners to obtain case studies of economic impact analysis. This system, which is delivered through an interactive website, allows practitioners to enter data on the characteristics of their own project. They can then view projects that are similar to theirs, and use the data to estimate the likely impacts of their project. This approach allows the application of simplified rules of thumb based on economic impact analysis cases that are similar.

The tool works by drawing from a case study database of over 100 economic impact assessments to estimate the range of economic impacts likely to result from a specific type of project in a defined setting. "It provides a form of 'analysis by analogy' in that it identifies a reasonable range for expected impacts of proposed projects, based on prior experiences."[52] It could serve as a screening tool for early stage project assessment.

4.4.5. Supply Chain Impacts

Traditional analyses of freight transport investments is focused on estimating the travel time, vehicle operating cost, and other direct user benefits associated with freight transportation investments. Cost reductions that are experienced by carriers can be assumed to be passed on to shippers. These direct user cost reductions can then be fed into an economic model (such as Implan) and the economic (indirect and induced) impacts can be estimated. This approaches does not include the secondary logistics related benefits that will occur as businesses reorganize to take advantage of lower transportation costs. This reorganization might include substituting transportation for inventory or consolidating distribution centers. Leaving out these benefits can underestimate total benefits by as much as 10 to 40 percent. A simple rule of thumb that can be used is to assume that second order benefits will add approximatelt 15 percent to the total benefits of the project.[53] [54] Third order benefits can add an additional 0 to 10 percent in benefits, depending on the size of the transportation cost adjustment. This approach can provide an order of magnitude impact of the benefits, but provides little information on how this benefit might be distributed between industries.[55]

Table 7. Rough "first cut" estimate of supply chain benefit from a 10 percent transportation improvement.

Infrastructure Benefit	Supply Chain Impact	Supply Chain Benefit Expressed as % of Operating Costs	Supply Chain Benefit Expressed as % of Transport Costs
10% Transport Cost Reduction	Lower Material Cost by substituting cheaper sources	0.1%	1.5%
	Consolidate Plants due to extended reach	0.2%	4.1%
	Switch modes and reduce shipment size, decreasing inventory	0.1%	1.2%

52 Strategic Highway Research Program, "Transportation Project Impact Case Studies System" database. Available at: http://www.tpics.us/Default.aspx.

53 Cambridge Systematics, Inc., Economic Development Research Group, Inc., Boston Logistics Group, Inc., Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects. Prepared for Office of the Secretary of Transportation, U.S. Department of Transportation, August 2006. Available at: http://www.edrgroup.com/pdf/large-scale-freight-guide.pdf.

54 Note that these values are not in the U.S. DOT TIGER guidance, but rather are provided as approximations that have been discussed in the published literature.

55 Cambridge Systematics, Inc., Economic Development Research Group, Inc., Boston Logistics Group, Inc., Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects. Prepared for Office of the Secretary of Transportation, U.S. Department of Transportation, August 2006. Available at: http://www.edrgroup.com/pdf/large-scale-freight-guide.pdf.

Table 7. Rough "first cut" estimate of supply chain benefit from a 10 percent transportation improvement. (cont'd.)

Infrastructure Benefit	Supply Chain Impact	Supply Chain Benefit Expressed as % of Operating Costs	Supply Chain Benefit Expressed as % of Transport Costs
10% Capacity Increase	Less Safety stock	0.1%	1.1%
	Rationalization of fleet and warehouse assets	0.01%	0.3%
Secondary Effects	Increasing service levels	Not quantified	Not quantified
	Converting cost savings into price reductions	Not quantified	Not quantified
	On-Demand supply chains	Not quantified	Not quantified
Total Benefits as Expressed as % of Cost Component	n/a	0.5%	8.2%

Note: These benefits are indicative and preliminary estimates only that are based on average companies in a broad cross-section of industries, including many that have little transportation cost and don't move physical product. More precise estimates that are targeted at specific Supply Chain Types should be developed using the tools referenced throughout this text.

Source: Boston Logistics Group, Inc.

5. SUMMARY OF ANALYSIS TOOLS

The table below summarizes some of the weaknesses and gaps in the different models. A model is necessarily a simplification of reality. Most of the weaknesses identified are model limitations that exist to make the analytical problem more manageable.

Table 8. Significant weaknesses.

Weaknesses Or Gaps	Tools
Failure to separate relocation effects from organic growth in a region. Growth in Region A may be offset by reduced growth in Regions B and C as industries change location decisions.	All regional and productivity models
Implicit assumption that transport improvements in Region A are not offset by similar improvements in Regions B and C.	All regional and productivity models
Productivity enhancements due to scale effects in Region A may be partially offset by reduced scale in Regions B and C.	All regional and productivity models
Focus on growth through relocation leaves out impacts of increased efficiency.	LEAP
Projections of growth by industry depend on static input-output tables. Inputs for a given industry change over time as technology changes and as relative prices of inputs change. Industry-specific projections based on current mix of inputs are unlikely to be accurate.	All models
Exclusive or dominant focus on highway networks leads to inability to consider properly rail freight and intermodal carriage.	REIMHS, PECAS, TELUM, REMI TranSight, others
Models not designed specifically for transportation require pre-processors to express improved freight performance as inputs the model can use to estimate growth or productivity impacts.	REMI
Some models represent improved performance with shorter distances between key points leading to lower costs. But these models do not take account of differences between modes in impacts on performance.	REMI
Models are relatively complex and have major data requirements. They do not incorporate rules of thumb or analytical shortcuts to provide low-cost methods of analyzing impacts of improved freight performance.	All models.
Most BCA models do not account for impacts on alternative routes of improved performance on a given highway segment. Typically, there will be shifts in traffic among routes in response to improvement on any one of them.	BCA models for highway improvement

BCA = benefit-cost analysis · LEAP = Local Economic Assessment Package · PECAS = Production Exchange Consumption Allocation System · REIMHS = Regional Economic Impact Model for Highway Systems · REMI = Regional Models Incorporated · TELUM = Transportation Environment and Land-use Model

Summary Comparison of Economic Impact Models

The table below compares the two most commonly used economic impact models.

Table 9. Comparison of economic impact models Regional Input-Output Modeling System II and IMpact analysis for PLANning.

Model Characteristics	RIMS II	IMPLAN
Economic Development Impacts (output)		
Business revenue Goods produced Services produced	Value of output by industry	Value of output by industry
Income	Yes	Yes
Employment	Yes	Yes
Investment	Yes	Yes
Model Features		
Cost	$275 per region $75 per industry, per State.	$350 for a county; $640 for a State.
Transparency	Very transparent – spreadsheet of multipliers.	Less transparent – model software.
Ease of use	Does not have user interface.	User friendly software interface.
Output detail	Does not show a breakdown of impacts by industry.	Shows breakdown of impacts by industry.
Incorporating dynamic effects	No – There are static inter-industry relationships which do not account for price elasticities, changes in consumer or industry behavior based on a direct effect.	No – There are static inter-industry relationships which do not account for price elasticities, changes in consumer or industry behavior based on a direct effect.
Adaptability	No, cannot add new industries.	Yes, new industries can be added.
Fiscal impacts	No, tax impacts cannot be estimated.	Yes, tax impacts can be estimated.
Multi-regional modeling	No	Yes
Time	Does not specify a time period to achieve all impacts.	Does not specify a time period to achieve all impacts.
Incorporating transportation system improvements	Requires user to develop a custom methodology.	Requires user to develop a custom methodology.

IMPLAN = IMpact analysis for PLANning · RIMS = Regional Input-Output Modeling System

Summary of Simplified Productivity Benefit Estimation Tools

The table below summarizes some simplified tools that have been developed to include the wider benefits of transportation investment that arise from productivity improvements, into BCAs and Economic Impact Analyses. These tools estimate how improvements in freight transportation system performance can cause additional benefits for businesses over the long term as they make changes to their operations. The economic benefit estimates produced by these tools are additive to the benefit estimates produced by BCAs and EIAs. These tools are available for free and relatively easy to use providing spreadsheet based menus for the user to navigate. The benefits estimated by the Highway Freight Logistics Reorganization Benefits Estimation Tool overlap with those estimated by the SHRP 2 C11 Reliability Tool and the SHRP 2 C11 Accessibility Tool. While the Highway Freight Logistics Reorganization Benefits Estimation Tool is designed to be used with only BCAs, the SHRP C11 tools can be used with BCAs or EIAs.

Table 10. Summary of simplified productivity benefit estimation tools.

Model Inputs, Outputs & Characteristics	Benefit Type	Summary
Highway Freight Logistics Reorganization Benefits Estimation Tool	Supply chain reorganization	The benefits estimated include reduction of shipping and sourcing costs, replacement of inventory on-hand with just-in-time delivery of inputs and whole-sale reformation of the supply chain. Information can be used to supplement a BCA analysis.
SHRP 2 C11 Reliability Tool	Reliability	Reducing late deliveries enables a reduction in inventories (safety stocks) and can allow more centralized warehousing and delivery processes to be put in place.
SHRP 2 C11 Accessibility Tool	Market access	Measures the economic impacts of transportation improvements on market access to both suppliers and buyers.
SHRP 2 C11 Connectivity Tool	Connectivity	The connectivity tool provides a way to assess the wider connectivity benefits of highway improvements that enhance access to alternative freight (and passenger) intermodal facilities.
SHRP 2 C11 Accounting Framework	Translates reliability, accessibility and connectivity into economic value	Converts the reliability, accessibility and connectivity measures into monetary values that can be used in a BCA or economic impact analysis.

BCA = Benefit-Cost Analysis · SHRP = Strategic Highway Research Program

Summary Comparison of Comprehensive Productivity Models

Table 11 below summarizes how the two models that are best equipped to estimate productivity impacts of freight transportation investments in the United States compare to each other with respect to their inputs and outputs.

Table 11. Comparison of productivity models Regional Models Incorporated and Transportation Economic Development Impact System.

Model Inputs, Outputs & Characteristics	Remi	Tredis
Economic Development Impacts (output)		
Business revenue Goods produced Services produced	Value of output by industry.	Value of output by industry.
Income	Yes	Yes
Employment	Yes	Yes
Investment	Yes	Yes
Productivity Impacts (output)		
Per man-hour	Yes	Yes
Per $ of capital	Requires exogenous calculation.	Yes
Labor/capital combined	Requires exogenous calculation.	Requires exogenous calculation.
Characterizing Inputs		
Transportation pre-processor	Requires the addition of TranSight or other transportation pre-processor. TranSight represents transportation impacts as modifying the generalized distance between counties. Generalized distance approach doesn't recognize variation in speeds and travel times between modes.	Provides input screens for changes in travel time, costs, reliability and transportation productivity for multiple modes. Includes inputs for changes in intermodal access.
Complexity	For some modeling exercises user may need to develop customized approaches to characterizing logistics inputs.	Model specifies logistics inputs. User may pick and choose how many supply chain and logistics inputs to use and for which modes.
Cost	$17,000 for a single geography with 3 digit NAICS code detail.	Cost is based on the length of subscription to the web tool and can be significant.

NAICS = North American Industry Classification System · REMI = Regional Models Incorporated · TREDIS = Transportation Economic Development Impact System

APPENDIX A. RESOURCES FOR PRACTITIONERS

The items listed below provide references that may be useful for practitioners who want to obtain an overview on the relationship between freight transportation and the economy. The list includes reference materials that summarize the economic literature, as well as guidebooks that provide step-by-step instructions on how to conduct different types of BCA, economic impact assessments and other types of economic analyses.

Freight Transportation Improvements and the Economy. U.S. DOT, http://ops.fhwa.dot.gov/freight/documents/improve_econ.pdf

Focusing on freight transportation, this report summarizes the results of the Federal Highway Administration's (FHWA's) work on the economic benefits of transportation improvements. In addition to this summary, two analytical reports are included as appendices: 1) Economic Effects of Transportation: The Freight Story; and 2) Transportation Infrastructure, Freight Services Sector and Economic Growth: A Synopsis. Three methods—macroeconomic and microeconomic research and general equilibrium approaches—have been employed to study the linkages between transportation and the economy. Each of these is discussed in this report.

NCFRP Report 12: Framework and Tools for Estimating Benefits of Specific Freight Network Investments. Prepared for the National Cooperative Freight Research Program. Prepared by Cambridge Systematics. 2011, http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_012.pdf

TRB's National Cooperative Freight Research Program (NCFRP) Report 12: Framework and Tools for Estimating Benefits of Specific Freight Network Investments provides a framework and tools designed to help estimate the private and public benefits of potential freight infrastructure investments.

The evaluation framework is intended to assist public planning and decision-making processes regarding freight; to supplement benefit/cost assessment with distributional impact measures; and to advance public-private cooperation.

The framework is capable of handling projects that span all of the different modes and able to assess benefits from a variety of project types, including those that are designed to improve freight operations, as well as those that would generate more capacity through infrastructure expansion.

Handbook: Assessing Local Economic Development Opportunities with ARC-LEAP, Appalachian Regional Commission Local Economic Assessment Package. Prepared by Economic Development Research Group, Inc., January 2004, http://www.arc.gov/assets/research_reports/HandbookAssessingLocalEconomicDevelopmentOpportunitieswithARCLEAP1.pdf

The ARC-LEAP model serves three related purposes, each aimed at helping practitioners identify target industries for economic development. The first is to provide a tool for local practitioners to assess current economic conditions and likely future trends. The second is to provide a diagnostic tool to aid practitioners in targeting industries that can provide the basis for economic development. The third is to provide an analysis tool for assessing the effects of policy (e.g., tax) changes and new investments (e.g., transportation improvements) on the attractiveness of an area for different industries.

NCHRP Report 456: Guidebook for Assessing the Social and Economic Effects of Transportation Projects. Prepared for the National Cooperative Highway Research Program, Prepared by David Forkenback and Glen Weisbrod. 2001

This report presents guidance for practitioners in assessing the social and economic implications of transportation projects for their surrounding communities. Presented in guidebook format, the report identifies current best methods, tools, and techniques, based on an extensive literature review and comprehensive survey of State departments of transportation and metropolitan planning organizations.

NCFRP Report 10: Performance Measures for Freight Transportation. Prepared for the National Cooperative Freight Research Program, Prepared by Gordon Proctor Associates, 2011, http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_010.pdf

TRB's National Cooperative Freight Research Program (NCFRP) Report 10: Performance Measures for Freight Transportation explores a set of measures to gauge the performance of the freight transportation system.

The measures are presented in the form of a freight system report card, which reports information in three formats, each increasingly detailed, to serve the needs of a wide variety of users from decision makers at all levels to anyone interested in assessing the performance of the nation's freight transportation system.

Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects. Prepared for Office of the Secretary of Transportation, U.S. Department of Transportation, Prepared by Cambridge Systematics, Inc., Economic Development Research Group, Inc., Boston Logistics Group, Inc., August 2006, http://www.edrgroup.com/pdf/large-scale-freight-guide.pdf

The core of the economic analysis framework for evaluating large-scale freight projects is a Five-Step Analysis process: 1.) Identify the nature and transportation purpose of the project, 2.) Identify the nature of expected economic impacts, 3.) Apply transportation impact evaluation tools, 4.) Apply economic impact evaluation tools to assess the magnitude and nature of economic effects actually projected to occur for elements of the economy that are either directly or indirectly affected by freight system costs and performance, 5.) Apply decision support methods to identify the substantial positive and negative impacts of the project for the economy (at the local/state or national level).

The Economics of Transportation Systems: A Reference for Practitioners. Prepared for Texas DOT, Prepared by Center for Transportation Research. January 2013, http://www.utexas.edu/research/ctr/pdf_reports/0_6628_P1.pdf

Provides an overview of economic analysis techniques for transportation practitioners. It is designed for those who wish to acquire knowledge of the subject and may not have a background in economics.

NCHRP Report 463: Economic Implications of Congestion. Prepared for the National Cooperative Research Program, Prepared by Weisbrod, Glen; Vary, Don; Treyz, George. 2001, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_463-a.pdf

This report focuses on the measurement of congestion impacts on transportation system performance and the measurement of business costs affected by congestion. The report describes an analytic framework and sketch planning tool, the "Congestion Decision Support System" (CDSS), which was developed during the course of this project for analyzing the economic impacts of congestion on businesses.

APPENDIX B. RELEVANT ECONOMIC LITERATURE

This section provides an overview of the economic literature related to freight transportation and the economic impact on the economy. Some relevant concepts and how these have been operationalized in research are discussed. There is vast literature on this topic. The review below is not an exhaustive examination of all the relevant studies; rather it seeks to discuss some of the most relevant work in the field related to examining freight transportation, cost and competitiveness.

Historical Importance of Freight Transportation to the National Economy

U.S. economic development has historically been shaped by freight transportation improvements. In the early 1800s, investment in canal infrastructure, such as the Erie Canal, opened up new production areas for grain in the interior of the U.S. Beginning in the 1830s, railroads began to play a more important role in the transportation of commodities. Throughout the 1800s, a whole economy of agricultural, mining and manufacturing firms grew up around expanding railroad networks. Studies of the market access impacts of railroads and waterways have found large economic impacts on GNP. (Donaldson & Horbek, 2013)

Beginning in the 1950s, investment in the interstate highway system served to promote additional growth by more closely linking regional markets together with accessible and reliable truck transport. The impact of investments in the highway system was studied in the early 1990s by David Aschauer and Alicia Munnel who examined the impact on the economy of all public capital. They were followed by a number of studies focused on highway transportation (Nadiri and Mamuneas, 1996; Madrick, 1996; Sturm et al., 1997; Weisbrod, Vary and Treyz, 2001; FHWA/ICF Consulting, 2002). Nadiri's work traced the impact on business costs of highway investment; he found high returns, especially in the period when the Interstate was becoming an extensive network. All of these studies were concerned with the whole economy.

One limitation of these studies was that they sought to study the link between industry productivity and levels of highway inventory, but they did not capture actual accessibility improvements. Research by Eberts on establishment-level localized productivity effects sought to address this concern by employing measures of highway accessibility (Eberts, 1997). Studies have identified non-linearity in the relationship of measures of transportation accessibility to firm productivity (Melo, 2012).

Regional and Industry Studies

There have been many studies specific to particular industries or regions that have addressed the impact of transportation infrastructure on industrial location. These studies have sought to examine firm-level decision making processes to determine what factors were important in location decisions. Location studies have employed both surveys of individual businesses, as well as aggregate data to examine location decisions. These studies have focused on a number of different areas, including manufacturing (Bartik, 1985; Walker and Greenstreet, 1991), small business startups (Bartik, 1989), and high technology (Toft and Mahmassani, 1984). The Regional Economic Models Inc. (REMI) model has been utilized in a number of research projects to estimate the effects of transportation on the cost competitiveness of local businesses

(Treyz, 1992). The statewide impacts of transportation on business location decisions have been examined with REMI in States including Wisconsin, Indiana, and Iowa.

The literature on economic geography contains numerous relevant research approaches to the study of industry location decisions. Interregional trade and economic geography modeling utilizes estimates of transportation cost and accessibility to differential inputs as the basis for explaining wide differences in regional productivity (Krugman, 1995). Studies have shown that degradation of the transportation system can reduce the productivity benefits and scale economies associated with industry agglomeration.

Containerization and other improvements in freight transportation have continued to lower barriers to trade internationally. The globalization of supply chains has served to lower production costs. It has opened new supply and consumer markets for U.S. businesses across the world (Levinson, Marc, 2006). Throughout history, each advance in transportation technology has created new markets for businesses, spurring economic opportunities, competition, job creation and economic growth.

Freight Transportation as a Foundation for Markets and Productivity Growth

In general, transportation improvements provide the foundation for new markets. At the most basic level, freight transportation allows production and consumption to occur at different locations. Transportation is necessary for economic specialization. Freight transportation allows firms to specialize in producing the products for which they are best suited and to trade with firms to obtain products that can be made more efficiently by others. Economic specialization allows firms to increase their productive capacity, allowing for increases in real income without using additional resources. Access to new supplier markets is an important benefit of highway investments. Studies of the economic efficiency benefits of greater access to diverse inputs were examined in work by Krugman (1991) and Fujita et al (2001).

In a broader context, by allowing businesses to purchase and sell products in a larger geographical area, improved freight transportation allows firms and regions to engage in economic activities for which they have a comparative advantage. Improvements in the existing freight transportation system allow firms to make incremental improvements in accessing larger markets and this creates economic value through incremental improvements in opportunities for specialization. Simply put, enhancements to the freight transportation system can unlock opportunities for productivity improvements and economic growth at the regional, national and international levels.

The contributions of freight infrastructure to productivity are critical to the performance of the economy. Another way to think about the importance of freight infrastructure improvements is to consider their impact on the delivered cost of products and services produced by firms in the economy. Because transportation serves as an input into every other sector of the economy, efficient transportation infrastructure investments can have an impact that ripples throughout the economy. Reduced transportation costs allow firms to deliver more products and services for the same price.

Efficient investments in freight transportation infrastructure have the greatest impacts on those sectors that are most reliant on freight transport, such as manufacturing industries.

As noted above, economists have attempted to measure the benefits of freight transportation investments at the national level using data on investment in infrastructure and private sector productivity growth. Macroeconomic studies completed by economists Ishaq Nadiri, Theofanis Mamuneas and others have shown a strong relationship between infrastructure investment and economic growth. Returns to investment in highway infrastructure were highest during the 1950s and 1960s. Following the completion of the interstate network in the late 1960s, returns to investment have fallen to levels similar to private investment.

The contribution of the highway network to national productivity growth has fallen from an extremely large 31 percent in the 1950s to a still substantial 7 percent in the 1980s. The contribution to productivity growth estimates how important the highway network has been to overall growth in technological change and innovation. Even with critical advancements in technologies in all sectors of the economy, the highway network still plays a critical role in stimulating improvements in productivity growth in the economy at large. In short, a significant body of research has concluded that public investment in transportation infrastructure has created large benefits for society.

On a regional basis, a number of factors complicate this story. Studies have found that highways have a differential impact across industries. Some industries grow as a result of reduced transportation costs, while others may shrink as economic activity relocates. Highways affect the geographic allocation of economic activity, raising the level of economic activity in the counties or regions that they pass directly through, but drawing activity away from adjacent counties. (Chandra & Thompson, 2000)

Linkages between Freight Transportation and the Economy

A representation of the linkages between transportation and economic development is shown in the Figure 5. Efficient transportation infrastructure investment affects system performance. Transportation investments increase transportation system capacity, efficiency, reliability and level of service.

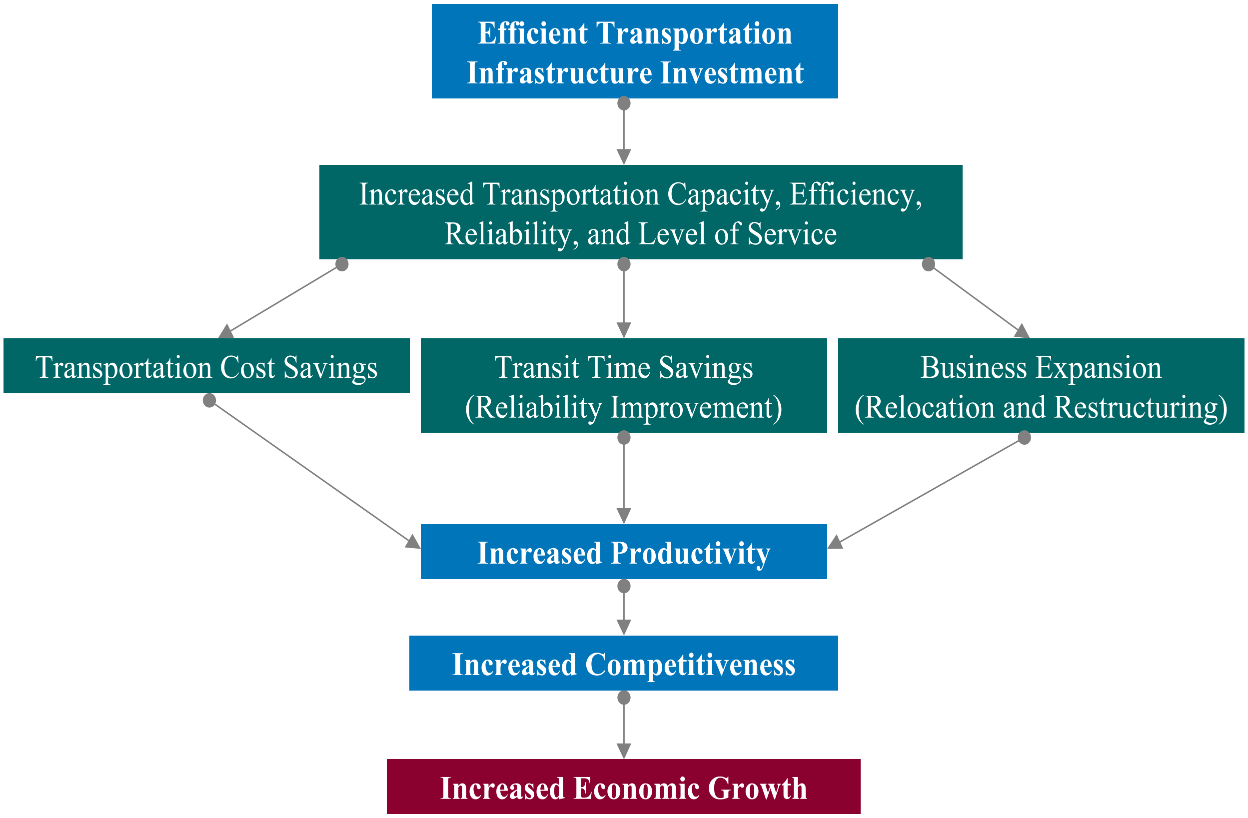


Figure 5. Diagram. Impacts of efficient transportation infrastructure investment.

These improvements in the transportation system lead to transportation cost savings and transit time savings, which are captured by traditional benefit cost analyses. Transportation infrastructure investments also result in business expansion, relocation and restructuring in the long-run. Businesses change their operations in response to changes in production costs. The reduced cost of transportation encourages businesses to restructure and use more transportation in the long-run. These business reorganization benefits have been the focus of FHWA's Freight Benefit Cost Study (ICF, HLB, LBG, 2002).

Of central importance to this analysis is that supply chains are not static. Variables such as factory and distribution center locations are constantly changing, and these decisions always reflect current and expected conditions in terms of cost of freight carriage and the relative costs of transportation and of inventory. When evaluating the impacts of reduced cost or improved performance (speed and reliability), it is important to take account of the effect on the supply chain as it is when the improvement occurs and how it is likely to change in response to improved goods movement. The simple table below shows this as first and second-order effects of freight infrastructure investments.

Table 12. First and second order effects of freight infrastructure investment.

First-order effects	Second-order effects
Reduced cost of shipping goods (including reduced damage and increased speed and reliability of trip time)	Higher volumes can be concentrated in fewer facilities with longer moves, so inventories can be reduced.
Firms can ship to farther markets and draw from more distant supply sources	Different inputs, materials or components become feasible. Different production methods are possible and also better goods for same cost.

FHWA conducted a comprehensive literature review and developed an economic framework to evaluate second order benefits (ICF, HLB, LBG, 2002). In addition, FHWA funded the development of a tool to allow policy makers to include second order benefits into traditional BCA (HDR, 2008). The tool works as an add-on to traditional benefit-cost analysis. A different approach is taken to estimating reorganization effects based on the use of the "field of Influence" technique and Ratio Allocation System (RAS)[56] adjustment of input-output account in a recent freight study (CFIRE, 2012). One can also consider third-order benefits which would include gains from additional reorganization effects such as improved products, new products, or some other change.

Other effects that policymakers may consider could include increases in regional or national employment or increases in income. A number of studies have used input-output models to estimate the impacts of freight transportation improvements on regional economies (CSI, 2005, 2008). One issue associated with these types of studies is that improved freight transportation may change the inter-industry purchasing patterns that are embodied in regional input-out tables. It is thus difficult to capture dynamic changes that may occur in the supply chain over time. There has also been some confusion over how to distinguish between the benefits and costs of freight transportation investments accounted for in traditional BCA studies and the impacts that are accounted for using economic impact analysis. The TREDIS sketch planning tool was developed to provide a framework to evaluate both of these types of impacts. (Alstadt, Weisbrod, 2008) FHWA also provides an economic analysis primer that provides guidance on what types of impacts should be considered in a traditional BCA. (U.S. DOT, 2003)

Research on mode choice may also help to inform economic impact and BCA of freight transportation projects. FHWA is currently conducting research to more fully understand the economics of mode choice. Using the Freight Analysis Framework (FAF), this research is examining the relationship between the types, characteristics and value of commodities moving in different corridors and their sensitivity to mode shifts. This can be an important issue for planners and policymakers. The value of commodities moving in a corridor may make some corridors more sensitive to mode shifts caused by external price shocks. For example, if there is an increase in the price of fuel, lower value commodities may be more likely to shift from truck to rail. It is important for benefit cost calculations to consider these types of dynamic market effects when forecasting future freight volumes and the benefits of proposed infrastructure improvements that are based on them.

56 This is a method to make adjustments to the I-O tables to reflect changes in the economic structure, which can result from transportation infrastructure improvements.

The mode choice decision includes a complex array of factors. The alignment of rail services with buyer supply chain processes and systems can serve as a market barrier for switching between truck and rail services for some. (Norbridge, 2009)

The value of commodities moving in different corridors affects the benefits that can be achieved from improving the infrastructure in these corridors. In general, you would expect that investment in infrastructure for traffic lanes with a higher value of goods would have greater benefits. Agencies often need to determine how to use limited funding and make choices that focus investment. Incorporating the value of freight into benefit cost calculations and performance measurement can be important. This is particularly important for understanding the inventory costs of freight delayed in transit. The Texas A&M Transportation Institute (TTI) recently developed a methodology to incorporate the value of freight into their Urban Mobility Report. (Eisele, Schrank, Bittner, and Larson, 2013)

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APPENDIX D. RESEARCH AGENDA

Introduction

This appendix describes a research agenda to build on the analytical frameworks and strengths and weaknesses of the techniques described above. This research agenda targets gaps in knowledge that have been identified, weaknesses in existing tools, or areas where new data and methods have recently become available, but have not been put to use. The collection of research ideas in this section is different from other more comprehensive research agendas. The SHRP 2 Report S2-C20-RW-2 Freight Demand Modeling and Data Improvement Strategic Plan has developed a wide ranging freight research agenda.[57] Project NCFRP 48 is also developing ideas for a future research agenda for TRB freight research. While there is some overlap between these different projects, the research agenda in this document is focused specifically on measuring the productivity and competitiveness benefits of freight transportation investments. While we do address a broad range of data, modeling and planning issues, all of these research ideas are targeted towards the characterization and measurement of the impact of highway freight infrastructure investment on productivity.

The supply chain is an important area of research where there are significant gaps. Much of the productivity impact of improvements in freight carriage comes from adjustments in the supply chain. This is sometimes called the reorganization effect. It is important to understand that this is a broad effect. As well as changes in highway or rail routes and location of distribution centers, it also encompasses factory locations, LTL terminals, intermodal terminals, and, possibly, port facilities. Supply chain impacts are most important for the movement and temporary storage of high-value freight—parts or intermediate products moving to factories, finished goods moving to distribution centers and on to retail outlets. Supply chain impacts may be particularly important for components that are necessary to continue production in a manufacturing operation, even if these supplies do not have a high value.[58] Supply chains constantly adjust as shippers seek to optimize logistics costs. As cost of carriage falls relative to inventory cost, lengths of haul increase and more inventory is held in fewer distribution centers.

We identify a set of research projects below that refine the existing understanding of the linkage of freight transportation to the economy. These consider how economic effects vary for different types of supply chains, different types of segments, and other factors. For each project we specify the research need, how it contributes to FHWA achieving its mission, provide an estimate of the scope and scale of the project, consider the likely time required to carry out the project, and suggest what stakeholders would need to be involved in the project.

The overall goal of this research agenda is to identify projects that will improve FHWA's understanding of the linkage between freight transportation investment, performance measures and economic competitiveness. The proposed agenda incorporates the following gaps and associated projects:

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57 K.M. Chase, P. Anater, and T. Phelan, Freight Demand Modeling and Data Improvement Strategic Plan, Strategic Highway Research Program (Washington, DC: TRB, 2013). Available at: http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2_C20-RW-2.pdf

58 Freight Benefit/Cost Study: Highway Freight Logistics Reorganization Benefits Estimation Tool Report and Documentation. http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/bca_logistics/index.htm

Agenda Item 1 - Understanding the Supply Chain: It is through changes in the supply chain that improvements in transportation system performance are translated into economic competitiveness. Understanding the supply chain better will help planners and policymakers analyze and model how transportation system investments improve competitiveness.

Agenda Item 2 - Freight Data and Performance Measures: New data is becoming available to measure transportation system performance. This data can be used to better understand the performance of the transportation system in real time and to analyze the supply chain. Improved freight data can provide better inputs into economic models that are used to measure the benefits (including productivity improvements) of transportation system investment.

Agenda Item 3 - Modeling freight demand and the Supply Chain: Improved activity based and microsimulation modeling tools will be needed by planners to accurately estimate freight demand and to model the supply chain. These models are also needed to better assess multi-modal transportation and mode choice decisions.

Agenda Item 4 - Improved Economic Models and Tools: Connecting changes in transportation system performance with economic impacts is the final link in the analytical chain discussed here. Improvements in economic models could allow planners and policymakers to more easily use these tools and obtain accurate results.

We have identified the following projects below as promising areas for further study. These projects address each of the agenda items (AI) discussed above.

AI1 - Urban Supply Chains and Freight Modeling

Additional research is needed on supply chains. A supply chain orientation is needed throughout transportation research, modeling and planning. In order to understand urban goods movement and the productivity benefits of investing in freight transportation improvements, it is necessary to understand the typology of common supply chains that are used in urban markets. This can be helpful for modeling. Modelers need to know, for this particular supply chain, this is how you deliver goods and these are the things you need to know to model your market place. Modelers need research, approaches and short cuts to understand what is happening in their marketplace. This would be useful at the state and local levels. NCFRP 14: Guidebook for Understanding Urban Goods Movement developed information on some of these supply chains, but given the diversity of supply chains existing, more research is needed in this area. An understanding of how supply chains work can serve as the basis for understanding the productivity benefits of transportation investments and how to model these impacts.

Project Size: Medium

Time Required: 12 months

Stakeholders to Involve: Carriers and shippers, state and local freight planners

AI2 - Freight Fluidity Indexes

More research is needed on freight fluidity indexes. Freight fluidity indexes measure the end-to-end performance of the supply chain, providing measures of performance that are more in line with how private sector logistics professionals measure and experience the performance of the transportation system (freight shipment transit time). Freight fluidity indexes are feasible to do it, but many of the data sources are private. Additional research is needed to help planners develop these indexes and access the private sector data that is needed. Freight fluidity indexes could provide better performance measures to assess how transportation investments will impact the supply chain and generate wider productivity benefits.

Project Size: Medium – This would require outreach to stakeholders.

Time Required: 12 months

Stakeholders to Involve: ATRI, carriers and shippers, FHWA, state and local freight planners, port officials

AI2 - Guidance on Using Truck Probe Data

The truck probe data are an important source of information on the performance of the highway network. This type of data may become very important for assessing the value of transportation investments for truck carriers, shippers and industry supply chains. This data may also serve as a valuable resource for conducting more detailed assessments of the impacts of transportation system performance on localized industry productivity.

Some states are using truck probe data from private sources and all states have access to the National Performance Management Research Data Set (NPMRDS). In the future there will be more vehicle probe data available. There is a need for information on how to use this data for performance measures and for research. How do you transform this data into useful information? The NPRDMS data has limitations and there are some holes in the data coverage. High volume corridors are missing. Approximately 30% of the intervals are missing. The problems get worse when you get down to lower level roadway types. There is a lot of variability in the data. There is a need to clean up the data and validate it against other sources. Other vehicle probe data has similar problems. FHWA could identify standard approaches to addressing these issues. Another issue is that the vehicle probe data set doesn't have ramp locations. When freight planners want to track the origin-destination performance, if they are missing ramp locations, it is hard to estimate the transit time for corridors. They may be missing some of the most congested segments.

Improved methods and approaches for using this data would facilitate the use of this data for performance measures, assessing the value of transportation investments and for measuring the productivity benefits associated with highway investments that improve performance.

Project Size: Medium

Time Required: 12 months

Stakeholders to Involve: ATRI, policymakers interested in performance measurement, major carrier and shipper groups, MPOs, DOTs, Researchers

AI2 - Cost of Delay by Commodity, Industry Type or Geographic Region
The benefits of transportation investments differ significantly across different commodity types, industry types, or geographic regions. Shippers with high value goods incur greater inventory costs from delays. Manufacturers with just-in-time inventory management systems can incur significant costs if unexpected delays in the delivery of supplies interfere with production. FHWA could conduct research to more fully examine how the benefits of highway investment differ between regions or commodity types. Manufacturing regions, particularly those with high value products, would likely benefit more. This research could provide data inputs for the SHRP 2 C11 Reliability Tool, improving the utility of this tool. This research could also examine the relative impacts of predictable vs. unpredictable delay on the supply chain and cost. ***Project Size***: Medium ***Time Required:*** 12 months ***Stakeholders to Involve:*** Industry groups representing major carriers and shippers, state and local policy makers involved in benefit cost analysis
AI2 - Peak and Off-peak Traffic Impacts
Many methods for estimating the benefits of highway freight investments do not adequately address the different impacts on peak and off peak traffic. For freight, this can be a significant issue since trucks will often operate during off-peak hours to avoid traffic where possible. Different types of traffic may be moving during off-peak hours than are moved during the most congested hours of the day. FHWA could conduct research to identify approaches to addressing this issue specifically by understanding how travel by time of day (during congested periods) varies by region or other freight characteristics. The benefits of freight transportation system improvements for freight moving during congested periods could be more accurately characterized. It may also be important for this research to examine the transportation system as a whole, since examining individual regions may miss the important inter-relationships and linkages in freight transportation activity and operating patterns between regions. ***Project Size:*** Medium - This might require survey data which would be costly. Another approach would be to take advantage of existing new vehicle probe data from ATRI to understand the percentage of heavy trucks operating in off-peak hours. Existing data from vehicle classifiers and traffic counting stations could also be used to get generic estimates of the volume of trucks by type and time of day. ***Time Required:*** 18 months ***Stakeholders to Involve:*** ATRI, state and local freight modelers, state transportation officials involved with traffic counting

AI3 - Incorporating the Supply Chain Perspective in Freight Modeling and Planning
How can modelers understand market dynamics and the supply chain? How can they take advantage of the data explosion and leverage private sector data to improve models? New activity based and microsimulation models are providing tools to model the supply chain. How can planners translate and incorporate knowledge of local supply chains and local data into their models. More broadly, how can an understanding of the supply chain infuse all aspects of freight planning? Data limitations are currently one of the biggest barriers to a better understanding of the productivity benefits of freight transportation investments. FHWA could provide research to help freight modelers to take advantage of new public and private sector data that can improve the accuracy and utility of freight demand models that are needed to provide estimates of economic benefits. ***Project Size:*** Medium ***Time Required:*** 12 months ***Stakeholders to Involve:*** Private sector data holders, Carriers and Shippers, FHWA, state and local freight planners, port officials
AI3 - Promoting the Diffusion of Agent-based and Microsimulation Modeling of Freight Flows and Costs
There is great interest in using agent based and microsimulation modeling to forecast the response of the supply chain to changes in the transportation system. There are a number of different barriers to using these new modeling tools. One problem is that these tools are too complex for practitioners to use without a major investment of time. Many State DOTs, MPOs and local governments choose not to run the simulations in-house due to time constraints. Some have hired consultants to do this work, but many agencies may not have sufficient budget for this. Providing more user friendly tools or other approaches to making these tools more accessible to State DOT and MPO staff would be useful. These models may also require a more detailed understanding how supply chains work in different regions. Approaches to obtaining the data inputs required by these models are also needed. More accurately modeling the supply chain would provide the basis for a better understanding of the productivity impacts of transportation system investments. ***Project Size:*** Large ***Time Required:*** 24 months ***Stakeholders to Involve***: Freight modelers, state and local freight planners and policymakers

AI4 - Use of Vehicle Probe Data to Estimate the Freight Reorganization Effect

New data on vehicle speeds from cell probes vehicle probes, Bluetooth and other sources are becoming available. These data will enable new types of research and economic tools. FHWA could invest additional resources in developing approaches to using these data to estimate the economic and the wider productivity benefits of freight-infrastructure improvement.

The data could be used to conduct research on productivity benefits of highway investment with a much finer level of geographic detail. FHWA's Freight Benefit Cost Study estimated an elasticity of demand for transportation using V/C ratios from HPMS. It would be useful to find out how real-time data on actual speeds affect the results of this analysis. The greater level of detail on the movement of trucks by time of day and geographic area could allow for new types of research approaches to be employed to study the supply chain. This data could also make useful contributions to the economic literature on localized industry productivity effects of transportation investment.

Project Size: Medium

Time Required: 24 months

Stakeholders to Involve: ATRI, policymakers interested in performance measurement, major carrier and shipper groups, MPOs, DOTs, Researchers

AI4 - Time Lags for Transportation and Supply Chain Impacts

One relevant question for productivity impacts is the timing of the impacts. What is the time lag from an improvement in place on a segment to supply-chain adjustments and the reorganization effect which bring the full impact, not just to the shipper, but to the regional economy? Firms will be cautious about making new location decisions and decisions on scale of distribution centers and factories. It could take a few years for the full effect to be apparent. In further research on supply chains and the reorganization effect, the goal would be better estimation of both timing and magnitude. The effect of a given change in delay or speed, for example, will vary with the value, and perhaps other characteristics, of the traffic and with the nature of the regional geography and economy. This research might also examine whether small operational projects near freight centers have a measurable impact, or if productivity analysis would be more applicable for larger scale capital projects that affect speed and development in a mature built out transportation system. This project could also build on work conducted in projects SHRP C-3 and SHRP C-11. In addition, there is ongoing research in the National Cooperative Highway Research Program Project 8-99: Methodology for Estimating the Value of Travel Time Reliability for Truck Freight System Users and in National Cooperative Freight Research Program Project 46: Benefit-Cost Methodologies for Evaluating Multimodal Freight Corridor Investments. Both of these projects are ongoing so there are not final deliverables available yet.

This is a challenging, but worthwhile, line of research. In tracing impacts over several years, it is necessary to separate the effects of the freight improvement from many other factors influencing a region's growth. One possible approach would be to find similar segments or corridors in other parts of a region or in similar regions to serve as controls for purposes of comparison. Very careful thinking would be needed to design the work and the data requirements would be substantial. Nonetheless, the results would be of significant value.

Project Size: Medium

Time Required: 18 months

Stakeholders to Involve: Major shippers and shipper groups, carriers, carriers, freight planners, academic organizations involved in supply chain research, MPOs, DOTs

AI4 - Recent Changes in Supply Chains and the Freight Benefit Cost Equation

There has been much discussion in recent years over how changes in the cost of fuel may be encouraging firms to re-engineer their supply chains. The cost of transportation has also been influenced by changes in the hours of service rules and other factors. FHWA could conduct research to examine how recent changes in transportation costs may have altered the benefit cost calculation for freight infrastructure investment.

Project Size: Medium

Time Required: 12 months

Stakeholders to Involve: Major carrier and shipper industry groups, academic organizations involved in supply chain research, state and local public sector officials involved in freight planning

AI4 - Simplified Methods to Conduct Productivity Analyses

State and local policymakers are interested in conducting comprehensive analyses of freight transportation investments that include the full spectrum of benefits, including long term productivity improvements to regional or state economies. Analyzing the productivity benefits of transportation investments often involves the use of sophisticated modeling tools and may require more time and resources than policymakers have available. The SHRP C11 project developed sketch planning tools to provide simplified methods to incorporate productivity analyses related to reliability, connectivity and market access into BCAs and EIAs. There is still a need for more simplified approaches that can provide policymakers with data that can be used earlier in the planning process. This would include case studies, summaries from literature reviews, meta-analysis and rules of thumb for estimating productivity (competitiveness) benefits of transportation investments. This project could examine economic findings on scale economies, technological learning curves, agglomeration economics, price elasticities, productivity, supply chain reorganization or other relevant economic research to identify rules of thumb for estimating productivity impacts of transportation improvements. This project would build upon the research that has been conducted in the SHRP C03 and SHRP C11 projects. The SHRP C03 tool is a case study-based web tool that provides ranges of estimates for planners to estimate economic impacts such as the direct jobs attributable to a project. One shortcoming of this database is that "the case studies do not directly measure the economic value of efficiency benefits, such as travel time savings, operating cost savings, and reliability improvement, as well as productivity growth associated with increased accessibility and efficiency of business operations."1 The SHRP C11 project produced simplified planning tools to estimate some of the wider productivity benefits associated transportation improvements, but these tools are meant to be used in conjunction with a formal BCA or EIA analysis framework. This proposed project would be different and compliment and extend the SHRP CO3 case study database to include ranges for productivity and competitiveness benefits. Some of this information could be developed by actually applying the SHRP C11 tools to the existing cases, but this would not preclude also using the results of other existing research that is already available from a number of state and local agencies who have used more sophisticated methods. The results of this project would provide data to planners for considering the impacts of competitiveness at an earlier stage of the planning process (before using formal economic analysis tools) than now exists, similar to the data that is currently provided for direct benefits.

Project Size: Small

Time Required: 12 months

Stakeholders to Involve: State and local freight planners

AI4 – SEGMENT-LEVEL IMPACTS

Many methods of assessing the benefits of highway improvements do not capture how these benefits differ across different types of highway segments. For instance, improvements to intermodal connectors, border crossings, or highway segments that are air quality hot-spots could have higher levels of benefits than other highway improvements. FHWA could conduct research to identify approaches to estimating productivity benefits on key segments. The research could highlight which segments or types of segments had the best B\C ratios for investments and which were associated with more significant productivity impacts. This work could build upon and utilize the SHRP2 C11 Intermodal Connectivity Tool. The results of this work would provide a more comprehensive documentation of the wider productivity benefits associated with investment in intermodal connectors.

Project Size: Medium to large - project size would like vary based on the number of different types of segments considered and the number of benefits included.

Time Required: 12-18 months

Stakeholders to Involve: State and local policy makers associated with air quality, intermodal facilities or border crossings; community organizations interested in the environment; academic research organizations that have done related work.

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