# Guide to Quantifying the Economic Impacts of Federal Investments in Large-Scale Freight Transportation Projects

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**Office of the Secretary of Transportation,**
**U.S. Department of Transportation**

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August 2006

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# ACKNOWLEDGMENTS

This report was funded by and prepared for the Office of the Secretary of Transportation (OST) of the United States Department of Transportation (U.S. DOT). It was commissioned by OST as part of an effort to develop guidelines for evaluating large-scale freight projects that span the interest of multiple modal agencies (Federal Highway Administration, Federal Railroad Administration, Federal Aviation Administration, and Federal Maritime Administration).

It was prepared by the team of Cambridge Systematics, Inc., Economic Development Research Group, Inc., and Boston Strategies International, Inc.

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The materials developed by the authors – including analysis steps, impact measures and available tools – were designed to build upon and complement concepts developed in a variety of other reports and guides that also address the economic impacts of multimodal freight investments. Those documents are listed in the bibliography at the back of this document.

# 1 Introduction

## 1.1 Background and Purpose of This Guide

International trade has grown rapidly over the past 20 years and is projected to increase dramatically by 2020, challenging the capacity of our nation's transportation system to accommodate growing freight volumes. These challenges will be particularly severe at major trade gateways such as the Ports of Los Angeles and Long Beach, which handle over 40 percent of all of the containerized cargo that enter the United States and face projected growth in freight volumes of over 10 percent annually over the next decade.

The growth in trade with our North American Free Trade Agreement (NAFTA) partners is also stunning. Between 1997 and 2003, the value of merchandise traded with Mexico and Canada grew 32 percent, significantly faster than overall foreign trade, which grew by 27 percent during this time. The continuation of growth in foreign trade has resulted in record freight volumes each year, a trend that contributes to considerable congestion on our transportation system.

Beyond ports and border crossings, increasing freight flows have also begun to strain the nation's inland surface transportation network. More trade has meant more trucks on highways and increasing traffic congestion in urban areas and in major Interstate trade corridors. Plus, increases in rail freight volumes have challenged the capacity and reliability of the U.S. freight rail system highlighting the issues faced by the rail sector, including insufficient returns on rail capital investments that have limited the ability of the industry to increase rail capacity. The trucking sector also faces a number of challenges, including constrained staging and rest areas and new regulations that restrict operations, such as changes to the hours-of-service rules.

When combined, these trends paint a worrisome picture for the state of the U.S. freight system. U.S. domestic freight tonnage is predicted to increase by 57 percent between 2000 and 2020, and if trends continue, growth in freight volumes will exceed increases in freight capacity for the foreseeable future, causing congestion throughout the surface transportation system and decreasing the reliability of freight shipment times. As congestion increases and reliability decrease, the transport and supply chain costs will go up, raising prices for U.S. consumers and lowering the competitiveness of U.S. businesses.

Ensuring sound investments in large-scale freight projects, therefore, is extremely important. The purpose of this guide is to provide a thorough economic analysis framework to assess the benefits and costs of potential freight investments.

Application of this guide, and the analytical steps recommended, is intended to ensure that freight projects are appropriately considered in national, regional, and state decisions about the future of transportation system investments. In addition, the high costs of these projects emphasize the need for public/private partnerships to amass the funds necessary for their successful completion.

Although this guide recognizes the importance of other social and environmental effects, the focus is on economic effects and the secondary passenger benefits that often accrue due to freight projects. Given this emphasis, the guide covers topics such as:

- National scale of benefits – economic benefits from freight projects impact industry shippers and receivers across the country (and internationally), not just the location of a freight project;
- Public versus private benefits – when considering the potential for public/private partnerships, it is imperative to maintain a careful accounting of public and private benefits, which are particularly relevant to freight transportation; and
- Logistics and supply chain effects – measuring the economic impact of freight investments requires the analysis of benefits to shippers and receivers of freight in terms of both "first order" direct transportation effects, and "second order" logistics, distribution, supply chain, and broader economy-wide implications.

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 in terms of its intended impact on improving freight and non-freight travel conditions. This is needed to ensure that those transportation effects and their consequences are properly evaluated.
2. Identify the nature of *expected economic impacts* in terms of the elements of the economy that feel they have a stake in seeing the project occur. This is needed to ensure that those economic effects and their consequences are also properly evaluated.
3. Apply *transportation impact evaluation tools* to assess the magnitude and nature of transportation system performance effects actually projected to impact shippers and carriers.
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 remainder of the guide provides extensive detail on all five of these steps, models and data to support economic and transportation analysis, and case studies that highlight the application of the five steps.

# 1.2 Emergence of Large-Scale Freight Projects

Large-scale freight projects are capital improvement projects that focus largely on improving the flow and capacity of moving goods, and typically cost between $100 million and several billion dollars. They may involve rail, roadway, air, or marine modes of travel. They can be right-of-way (or corridor) projects, such as new or expanded railroad lines, truck roadway routes, tunnels, or overpasses. They can also be terminal projects, such as expansion of airport freight facilities, marine port facilities, rail terminals, or intermodal truck/rail terminals.

Nearly all large-scale freight projects are multimodal or intermodal projects such that they impact the movement of goods on more than one mode. All air freight and marine freight movements, for example, also involve interchanges to ground transportation (truck or rail) for pickup from shippers and delivery to recipients. In addition, a large share of rail freight movement also involves prior and/or subsequent movement by another mode of transportation, generally truck.

***Freight-Oriented Projects***

Right of Way
- Truck-only or truck-priority routes
- Freight Rail Lines
- Freight Yards (truck or rail)
- Rail or truck route bridges or tunnels
- Freight route overpasses or flyovers

Terminals
- Rail/truck intermodal terminals
- Rail service to marine ports
- Air freight truck distribution centers
- Border facilities for truck/rail only
- Inland and satellite port facilities

The need for major capital investment in large-scale freight transportation facilities has grown as a result of several trends that have accelerated in the past decade:

- Increasing *international trade* that focuses more import and export processing at major international air/sea gateways and truck/rail border crossings;
- Increasing growth of *national and international scale* industries and markets that expand average freight shipping distances;
- Increasing adoption of *new production and logistics processes* – including integrated supply chains, just-in-time scheduling, and dependence on overnight express shipping – all of which increases freight trip-making;
- Increasing *consolidation* among air, marine and rail transportation companies that focuses activity on a smaller number of terminal and interchange sites; and

- Increasing *incidence of congestion delays* due to capacity constraints and bottlenecks at various entry/access ports, terminals, freight distribution/sorting yards and intersections or bridges along freight routes.

These trends not only increase demand for large-scale projects, they also increase the potential economic development stakes involved in completion of such projects. That is because large-scale freight projects as described above can have major implications for business productivity, economic development, and business location and expansion decisions. That does not mean that all such projects have benefits justifying the investment, but it does mean that the potential magnitude of the benefits – as well as the costs – can be substantial. While the estimates of costs have been relatively straight forward, accurate and comprehensive, measurement of first order and higher order benefits has remained a major challenge. This makes it critical that appropriate methods be applied for evaluating public investments in such projects.

***Motivations for Large-Scale Freight Projects***

- Reduce Congestion
- Enhance Safety
- Expand System Capacity
- Improve System Performance
- Enhance Market Access
- Realize Logistic Efficiencies
- Improve Environment

## 1.3 Challenges for Evaluating Large-Scale Projects

Local, state, and Federal transportation agencies have a responsibility to assess the relative advantages and costs of major public capital investments to ensure that funds are invested wisely. Nevertheless, large-scale freight projects have a series of distinguishing features that makes them particularly difficult to evaluate. They include the following:

- Large-scale freight projects typically have economic development (productivity, trade, jobs, and income) impacts that require *public benefit consideration*.
- Proposals for major freight facilities (and the highway or rail corridors serving them) often have *national level significance* based on the dispersed pattern of freight trip origins and destinations and involve costs of a geographic scale beyond the jurisdiction of local and state governments, thus indicating potential funding consideration at the Federal level.
- Most proposals for major freight projects involve *multiple modes of travel*. That complicates the analysis of capacity needs and benefits since there can be numerous alternative freight options across modes. It also complicates benefit-cost comparison because some modes involve public roles for funding facilities and operating services, while others are more traditionally private.
- Most proposals for major freight projects have both public and private sector benefits and costs. That makes it particularly difficult to assess the size and incidence of benefits and funding responsibility burdens so that they can be

allocated among private shippers/recipients, transportation providers and public sector agencies.

These challenges can only be met by the adoption of analysis methods that can 1) span multiple modes, 2) distinguish freight impacts from passenger travel impacts, 3) distinguish local or state impacts from national level impacts, and 4) distinguish private benefits from public benefits. While the Federal government has previously funded development of various benefit-cost evaluation methods designed specifically for highway, rail, aviation and marine projects, it has not had a process developed for fully evaluating the economic impacts and benefits of freight investment involving combinations of those modes. This guide seeks to address that need and to provide a consistent methodology for use in demonstrating the expected economic impacts of freight investments.

## 1.4 Federal-Level Interest and Goals

The benefits and costs of improving commuter traffic congestion typically remain confined within a single urban area. Freight transportation, however, usually involves many more long-haul trips from origins in one region to destinations in many others. For example, improving a freight bottleneck near a seaport handling substantial international trade can result in beneficiaries throughout the country (and even the rest of the world). Given the interstate scale of goods movement, the Federal government has a more compelling role to play in large-scale freight projects. This role is challenging for at least three reasons.

1. U.S. DOT is increasingly being asked to support large-scale freight projects and there are not well defined, objective criteria and methodologies in place for comparing and making choices among projects when limited funding is involved.

2. The Federal government has a unique capability and responsibility to provide some form of coordination, leadership, support, and guidance to local and state agencies.

3. Federal agencies strive to ensure that public investments provide economic benefits for all Americans and do not merely subsidize private sector profit-making or re-distribute benefits between competing regions.

The goal of this work, therefore, is to develop a general framework or process that can be applied to systematically evaluate the nature of economic benefits and costs and their incidence among various private and public sector interests. This framework can also provide an objective basis for evaluating the appropriateness of Federal-level involvement in such projects and defining the appropriate level of Federal funding. A rigorous framework can also serve as a decision tool for comparing investments in alternative projects. Finally, it can help define an equitable allocation of cost-bearing among public and private sector parties. For such a framework to succeed, it must provide consistent metrics for national as well as regional impacts, and across all relevant modes.

Such a framework cannot be a single, universal software model, as the range of considerations and depth of analysis can differ widely depending on the type of project. Rather, the framework needs to provide a checklist and structure for ensuring full consideration of all major issues, designed as a transparent process that can be acceptable to local project sponsors (and their transportation planners and consultants). In order to satisfy these objectives, this guide describes a range of different analysis tools, selected from a toolbox of available transportation and economic models that can be applied to estimate a consistent set of benefit and cost measures.

## 1.5 Cost and Impact Perspectives

The nature of economic costs and benefits generated from freight-oriented transportation investments differs from those of more traditional transportation improvements (such as highway, transit, or airport/airway projects) that primarily serve passengers and only secondarily serve freight. The main difference is that the primary benefits of freight-oriented projects explicitly apply to a complex chain of private-sector manufacturing, logistics, and distribution processes. A typical chain of impacts has the following five elements:

1. *Carriers.* Many of the impacts of freight investments on transportation system performance are first encountered by private sector freight carriers, and that will generate certain direct travel time, cost, reliability, and accessibility and/or safety benefits to those carriers.
2. *Shippers.* Insofar as there is competition among freight carriers within a mode or between modes, the impact on carrier performance and cost typically is passed onto their customers, the freight shippers. In a very real sense, the freight shippers (rather than the carriers) are the users of the freight transport system, for it is their freight movements that are the real beneficiaries of time savings and improved arrival time reliability.[1] Shippers can further benefit insofar as they can reconfigure the scale, scheduling, and characteristics of their business operations and logistics processes over the long run.
3. *Industries and Markets.* Clearly, changes in the business operations of freight shippers also affect the freight recipients, and can also change freight shipper-recipient patterns. That can have further consequences for the market pattern of production, distribution and sales of supply materials, intermediate goods, and final products for other businesses. These effects can occur locally, regionally, around the nation and beyond.

[1] Assigning the user benefits of freight transport to shippers rather than vehicle drivers is consistent with the concept of assigning the user benefits of public transport to bus passengers rather than bus drivers.

4. *Non-Freight Impacts: Economic Development.* The ultimate impact of more efficient or lower cost operations is on business productivity (affecting profitability), which leads to changes in activity patterns that impact job and income creation and their location patterns. This income and employment effect is a public benefit.

5. *Other Public Impacts.* Another impact of changes in freight flow patterns is on business operations, which in turn can affect demand for various public and private facilities. That can have direct effects on public infrastructure costs and indirect effects on the environment, as changes in freight flows and economic activity can also affect energy resources use and pollution emissions.

This guide focuses on Elements 1 to 4. This last element is noted, but is not evaluated in this guide, as environmental impacts related to large-scale transportation project investments have already been addressed in other studies.

There are three crucial consequences that follow as a result of this chain of impacts: One is the need to classify projects and apply appropriate methods for estimating transportation system performance impacts in a way that reflects the nature of those impacts. A second is the need to recognize the differing effects that can result for freight carriers, shippers, and other users. The third consequence is the need to assess ultimate benefits for economic development and other public benefits. Thus, the evaluation of large-scale freight projects must be comprehensive in encompassing the different types of impacts, the different types of affected parties, and long-term implications for the economy from the public perspective.

## 1.6 Structure of this Guide

This guidebook is intended for use by Federal, state, or local officials interested in systematically assessing the benefits and impacts of large-scale freight system investments. It lays out a general framework as a series of consistent steps that should be carried out to conduct economic benefit and impact analysis for any proposed project. It is designed first and foremost to ensure full consistency regardless of the combination of railroad, marine, aviation, or road transportation modes being affected. It is also designed to provide full transparency in the calculation of economic costs and benefits. The guide is organized into four parts:

1. **Part 1 (Chapters 1 to 2)** describes the general approach by defining the types of projects, information needs and results addressed by the analysis framework. The first chapter summarizes these factors, while the second chapter lays out the basic series of steps involved.
2. **Part 2 (Chapters 3 to 7)** walks users through each of the five steps involved in classifying the project, defining evaluation issues, applying transportation analysis methods, applying economic analysis methods, and applying decision methods. At each step, there are options for more or less detailed methods to be used, depending on the nature of the project.

3. **Part 3 (Chapter 8)** provides users with a case study that illustrates the nature of large-scale freight transportation projects in the real world and the challenges involved in evaluating their economic impacts. Appendix B includes additional case studies that illustrate transportation impact analysis and economic analysis techniques that will be useful in evaluating future projects (however, these case studies do not follow the framework laid out in this guidebook in its entirety).
4. **Part 4 (Chapters 9 to 10)** describes analysis forms and tools that can be applied in carrying out the five steps.
5. **Appendices** provide an analysis of how freight infrastructure investments impact supply chain **practices** and costs.

# 2 GENERAL APPROACH

## 2.1 Design of the Framework

The analysis framework is designed around three fundamental concepts:

1. *A coherent classification and terminology.* Regardless of whether the project involves air, water, or ground-level modes of transportation, there should be a consistent set of terms used to describe the categories of parties who are involved in or benefit from freight transportation systems.
2. *A common set of analysis steps.* While differences in project scale, complexity, and orientation may call for different types of data and analytic tools, there should be a consistent set of steps applied for defining both evaluation issues and impact measures.
3. *A tiered approach for screening and analysis.* Since large-scale freight projects can be complex, there should be a way to initially screen projects to assess the possible range of potential benefits before committing to the investment of major resources for a highly detailed analysis. Only those projects that pass an initial screening should be subject to the more intensive analysis, and even then, the specific analytic tools can be tailored to the key issues relevant for that project.

The remainder of this chapter describes the proposed terminology, the sequence of analysis steps, and the tiered screening process. The five chapters that follow then provide details on the individual steps to be applied in carrying out the framework and its analysis process.

## 2.2 Categories of Affected Parties

There can be a myriad of different parties involved in using, operating, and benefiting from freight transportation systems. The affected parties can encompass all sectors of the economy – farmers, miners, manufacturers, utilities, transportation companies, brokers, distributors, wholesalers, retailers, service providers, government, and households. It is neither possible nor useful, however, to attempt to break out and separately measure the nature of freight project impacts on each of these parties. Therefore, a simpler set of distinctions is necessary for this analysis.

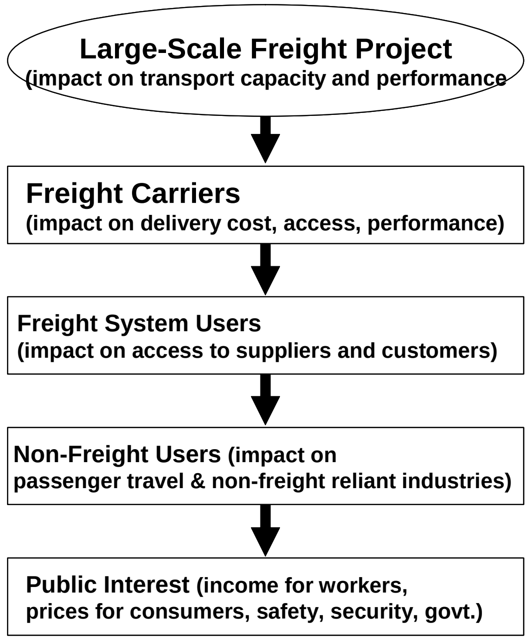
At one level, it is useful to first assess projects in terms of their overall societal benefit and then compare that to their total cost without breaking out the affected parties. After all, any project that does not generate significant overall societal benefits is not likely to justify the expenditure of Federal funds (unless there are some special public policy considerations). At another level, it is useful to also distinguish public and private sector interests, and also distinguish those that are directly affected from those that are indirectly affected. These distinctions can be important for determining an appropriate balance of public and private financing responsibility for a project.

Therefore, the general framework for analysis makes a distinction between four broad categories of affected parties: 1) *Freight Carriers* – providers of vehicles and services directly affected by freight transportation system changes; 2) *Freight Users* – the shippers who generate freight demand and are most often affected by its costs; 3) *Non-Freight Users* – who may also benefit as a side effect of freight transportation improvements;[2] and 4) *Consumers and General Public* – who may benefit in the form of greater income generation for workers, lower prices, and/or various environmental, energy, safety or security benefits.

The relationship between these four categories of affected parties is illustrated in Figure 2.1. It shows that improvements in freight facilities affect freight carriers, who may pass on the impacts to freight users, leading to additional secondary impacts on other parties and ultimately effects on income and productivity in the economy (as well as other possible environmental impacts). Depending on the specific freight projects being considered, some, but not necessarily all, of the elements of this sequence may occur and thus be important to evaluate. However, it is important to consider, at the outset, that any of the elements shown in Figure 2.1 could potentially be relevant for evaluating the overall economic benefits of large-scale freight projects.

[2] For example, car speeds may benefit as a result of new truck lanes or improved truck routes intended to address truck flow needs.

**Figure 2.1 Classification of Effects on Various Parties**




The importance of this classification becomes apparent later in the process, when overall project benefits and costs are portrayed in terms of their direct and indirect effects on public and private sector interests.

## 2.3 Five Basic Steps

Once the general parameters of a project have been established, the heart of the universal framework for evaluating large-scale freight projects is a Five-Step Analysis process. In its most basic form, there is no way to avoid these five steps if one is to assess the economic impacts of such projects. The steps are:

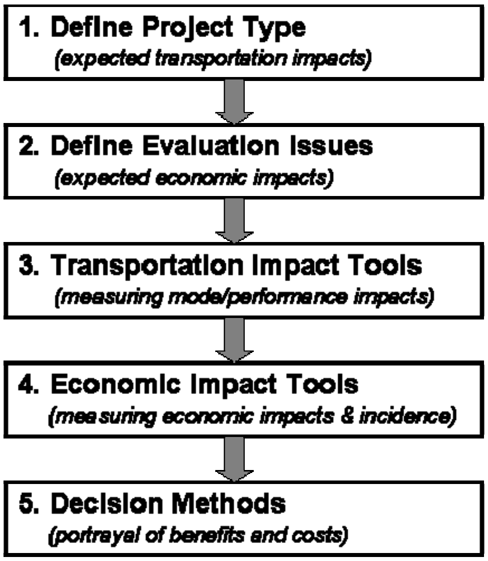
1. Identify the nature and *transportation purpose* of the project in terms of its intended impact on improving freight and non-freight travel conditions. This is needed to ensure that those transportation effects and their consequences are properly evaluated.
2. Identify the nature of *expected economic impacts* in terms of the elements of the economy that feel they have a stake in seeing the project occur. This is needed to ensure that those economic effects and their consequences are also properly evaluated.
3. Apply *transportation impact evaluation tools* to assess the magnitude and nature of transportation system performance effects actually projected to impact shippers and carriers.

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 relationship between these five steps is illustrated in Figure 2.2. It shows the sequence of how each step builds on findings from the prior step.

**Figure 2.2 Five Step Analysis Process**




**Difference from Traditional Project Assessment.** While the sequence of these five steps may appear to be quite obvious and elementary, it is actually a departure from traditional benefit-cost analysis approaches for transportation projects. In the traditional approach embodied in essentially all transportation benefit-cost analysis frameworks used for single modes in the U.S., there is no need for the first two steps that defines the project's transportation system changes and their economic value. That is because the traditional single-mode evaluation methods typically rely on a fixed and predetermined definition of the user benefit that encompasses the value of travel time saved, vehicle operating cost saved, and accident reduction. For large-scale freight transportation projects, however, we know that major motivations are frequently related to other issues, such as trade competitiveness, national security, reliability, capacity, and balance among modes, ports, or border gateways. So the framework in this guide carefully sets up the first two steps to identify the specific nature of potential freight transportation changes and their intended economic consequences. Those factors then provide criteria to be used for selecting analysis methods and reporting findings in the subsequent three steps.

**Structure of this Guide.** The key elements of analysis embodied in these five steps are summarized in Figure 2.3. Details of these elements and their use are discussed in more detail within Chapters 3 through 7.

**Figure 2.3 Key Analysis Elements of the Five Steps**

**Step 1 – Classify the Type of Project (Transportation Impact)**

Facility Location – local entry/access point, regional corridor, facility

Modes Involved – air, water, rail, truck, combinations of modes

Transport Change – capacity, access, speed/flow, and cost

Investment – expand existing facility, build new or alternative facility

**Step 2 – Define the Relevant Evaluation Issues (Economic Impact)**

National and international scale freight network capacity and level-of-service needs

Economic competitiveness, growth, productivity, and trade

Benefits to specific regions, modes, or industry-specific targets

Allocation of costs and benefits among affected parties, to assess equitable funding

**Step 3 –Tools for Calculation of Transportation Impacts**

Network analysis – providing links, nodes, capacity, and performance – rail, highway

Facility handling analysis – capacity/cost for ports, terminals, bridges, tunnels

Logistics analysis – ultimate cost implications of mode/facility choices

**Step 4 –Tools for Calculation of Expected Economic Impacts**

Form of economic impact – cost reduction, productivity, income generation, jobs

Geography of impacted markets – local, regional, national, international

Distribution of economic impacts – commodity and economic sector

Models – supply chain, regional economic growth, national productivity, int. trade

**Step 5 – Decision Methods**

Benefit/cost analysis

Cost-effectiveness analysis

Equity impact analysis

Multicriteria weighting analysis

## 2.4 Using the Analytic Framework in a Two-Tiered Analysis Approach

The framework is set up so that the five-step process can be conducted at two levels. First, an initial analysis can be conducted at a summary or "sketch planning" level, which can be completed with limited data and resources. Then, if the initial analysis indicates a potentially significant project benefit, a more "in-depth" level of analysis can be conducted. There are several reasons for preferring this approach:

- Freight data assembly and collection is often challenging and expensive. If the project costs and risks are relatively low, the costs of collecting data necessary to fully implement all five steps of this process may not be cost justified. Nonetheless, the implementing agency may need to demonstrate positive economic impacts and benefits to support a decision to proceed with a project.
- In the early stages of project planning, it may be useful to assess economic impacts as part of an alternatives screening process where a large number of alternatives are being considered and compared across a variety of performance dimensions. At this stage of project development, sketch planning methods are likely to be employed and there is a way to use the steps in this approach in this type of analysis. Subsequently, the second tier, more detailed analysis may be required to support high cost project decisions.
- It may be possible to justify project selection decisions on the basis of an initial assessment without consideration of second or higher order benefits if simple first order benefits are sufficiently high or low relative to costs that the decision of whether to proceed with the project or not may be obvious.

In cases such as these, it is possible to use this guidebook as part of a two part strategy: the more sophisticated analysis (Steps 4 and5) would be carried out only after the initial simplified screening process determines whether or not a proposed project appears to have total benefits even approaching the project cost. That can be done by initially focusing just on first-order effects determined in Steps 1, 2, and 3. The first order effects are typically travel time and cost savings for directly affected shipments and shipping patterns, and in some cases there may also be changes in volume if the project relieves a capacity constraint or bottleneck in the system. If any of the conditions described above call for a sketch planning analysis, an initial evaluation of the downstream economic implications of cost and growth changes can also be analyzed directly using spreadsheet-based methods (as discussed in Chapter 4 and illustrated by examples later in Chapter 8).

If the initial first order analysis demonstrates some potential for positive benefit-cost ratios, a more sophisticated *second level* of analysis may be advisable to then carry out. In this more rigorous approach, Steps 3 and 5 can be carried out with more detailed analysis methods that utilize freight network and logistics models, together with economic models, to separate the incidence of private and public sector costs and benefits.  Since transportation and economic simulation models are required to complete this second level of analysis, the resources required are substantially greater.  The available tools for accomplishing this are described later in Chapters 4 and 5.

## 2.5 Basic Information

There are separate data requirements needed within each step of the analysis process. These data requirements correspond closely to the individual analysis elements of the steps shown in Figure 2.3.  The form of these data requirements is summarized below.

**Transportation Impact Data**

- Step 1 (Classify the Type of Project) requires a description of transportation network *supply* conditions for scenarios representing conditions with and without the proposed improvement project.  This includes characteristics of transportation infrastructure and anticipated impacts to access, capacity, speed, and cost by mode.
- Step 3 (Transportation Impact) requires a description of travel *demand* patterns for those scenarios.  This includes volume of freight flow (vehicles and tons) by commodity and mode.  The analysis process in this task then estimates the impact on carriers (vehicle-miles of travel and vehicle-hours of travel, as well as variability in travel time and delivery access measures), and additional user (shipper) impacts on productivity and market access.

The specific transportation data that should be collected will differ depending on the nature of the project (i.e., the modes affected, the type of impact expected, and the specific transportation analysis tools that are required), the specific differences being mostly related to the form in which the data will be provided. (For example, will data be provided on annual affected VMT and percent of time congested or in total hours of delay estimated directly from a travel demand model?)  An important point to note is that the transportation impact data must be collected for all affected modes of transportation, which may be both freight and passenger modes if there are cross modal effects.

**Economic Evaluation Factors**

- Step 2 (Define the Evaluation Issues) calls for specification of the desired transportation and economic *performance measures*, which can include national freight capacity and level-of-service needs, and implications for economic competitiveness, growth, productivity, and trade levels.
- Step 4 (Economic Impact Analysis) requires a description of data needed to assess the *economic value* of those performance impacts.  This includes the dollar valuation of productivity improvements from freight cost, reliability, and speed changes (affecting market access and the supply chain), and the

incidence of economic growth impacts (in terms of spatial location and industry classification).

There are two additional requirements for information to assess the economic impacts of multimodal freight projects. One is the need for consistent measures of direct impacts that are equivalent among all affected modes. The other is the need for information on the commodity mix of affected freight flows, since economic impacts can differ depending on the industries affected.

**Data Collection Issues**

A data collection structure that is consistent and comprehensive is a good start, but it is intended as an inventory that will help an analyst take stock of what is available and how to select the appropriate analytical methods based on what data are available and what remains to be collected and assembled. An incomplete inventory does not preclude a robust analysis, but should provide a sober basis for stakeholder expectations. For example, the persistent lack of data about service levels and costs from private sector providers of truck, rail, air, and marine freight services has blunted the rigor of evaluating some large-scale freight projects. Nevertheless, there are ongoing attempts to overcome this data deficiency. For example, the National Retail Federation's "Port Tracker" model accesses private sector data to show the economic implications of trade flows. The framework in this report, however, is designed to avoid requiring proprietary service and cost data from freight carriers.

Instead, the framework allows for standard averages or "rules of thumb" to be used in assessing impacts on transportation operating costs and service levels for carriers. It also allows for simplifying assumptions that carrier costs are ultimately passed on to customers (shippers), who then incur additional cost impacts associated with freight logistics, distribution, and process scheduling. Such assumptions do preclude the possibility of distinguishing impacts on carrier profitability from impacts on shipper profitability, as both are part of the private sector impact. However, they do still allow for the ability to distinguish private sector impacts from public sector impacts.

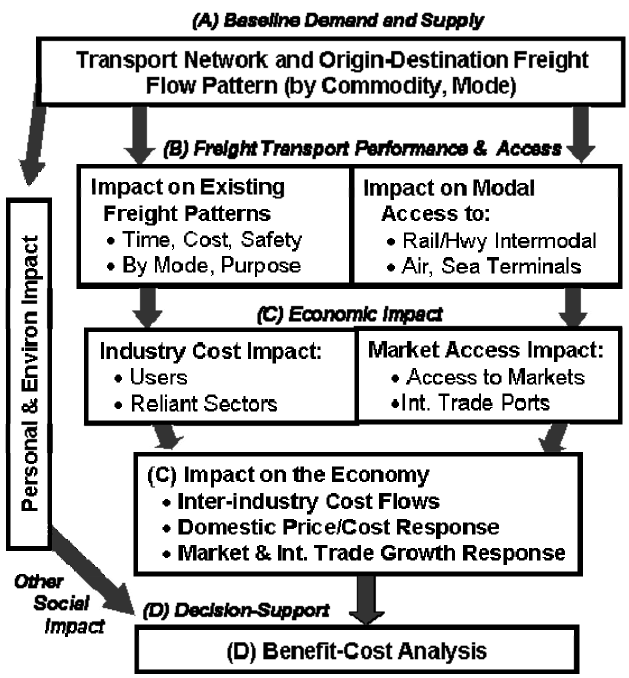
Finally, it is important to note that while analysis can be conducted without obtaining details on private carrier freight costs and service reliability measures that do not mean that such information is irrelevant. On the contrary, private freight carrier data of this type can be quite useful, particularly when highlighting problems unique to a specific corridor or bottleneck that already constrains available freight carrier services. Sometimes it is possible to obtain private information, particularly when proposals for large-scale facilities are likely to directly benefit private freight carriers and require active discussion between government agencies and private owners of rail, air, or marine facilities. There are many institutional issues involved in the process of initiating and pursuing that kind of dialogue, which are discussed in detail in separate studies of the National Cooperative Highway Research Program (see particularly: *Rail Freight Solutions to Road Congestion*, NCHRP, 2006).

# 2.6 Analysis Tools

The latter three steps of the Analysis Framework involve a series of transportation and economic analysis methods to evaluate transportation impacts, economic consequences and benefit measures. The framework is designed to be flexible so that simple spreadsheet tools can be used for a straightforward sketch planning level of analysis, or complex simulation model tools can be used for a more sophisticated and detailed level of analysis.

Figure 2.4 illustrates the key analysis issues covered by the analysis framework. This graphic provides the basis for a brief overview of the required types of tools. However, these methods are discussed further in Chapters 3 to 7, and also catalogued in Chapter 10.

**Figure 2.4 Analysis Components**




<u>(A) Baseline: Demand and Supply Characteristics</u>

The first step, illustrated by the top box in Figure 2.4, is to assemble baseline (current and forecast) information about freight flow patterns and the capacity and performance that is provided by transportation network facilities. This calls for two types of analysis tools:

- *Demand Side: Freight Forecasting Models.* For large-scale projects with long time horizons, it is particularly important to understand the forces that determine freight flows. Freight demand is driven by demand for products, which depends upon economic geography and the costs of transportation. A common approach is to use economic forecasts to determine commodity flow volumes, and to use transportation and logistics costs to predict traffic flows (origin-destination movements) by mode.

- *Supply Side: Network and Terminal Performance Models.* Ground transportation (highway and rail) systems have networks with fixed right-of-way routes that can be represented as links and nodes, each with capacity and cost/speed performance characteristics. (Toll facilities, freight terminals, and yards can be nodes in those systems.) Air and marine transportation have open travel routes, but terminal facilities that similarly have their own capacity and cost/speed performance characteristics.

(B) Impacts on Freight Transport Performance and Access

Given baseline demand and supply characteristics, tools are applied to assess the impact of proposed projects on freight transportation system use and performance, in terms of aggregate changes in time, cost, reliability, and safety. This is represented by the second tier of boxes in Figure 2.4, which makes a distinction between savings for projected/existing trips given existing market access patterns (the left box) and impacts associated with increased access to potential new markets and intermodal connections (the right box). It requires two types of analysis tools:

1. ***Individual Modes: Network and Terminal Performance Models.*** These tools (first used for the baseline analysis) must be reapplied to forecast how different types of investments will affect the functional operating capacity and performance characteristics of transportation facilities, given patterns of demand. Single mode models can address issues such as how dedicated truck lanes can reduce congestion and enhance throughput for both passenger and freight travel. Combinations of models spanning multiple modes can address other issues such as how changes in intermodal loading systems can affect speed and functional capacity of freight throughput. Changes in connectivity identified by these models can also be used to identify opportunities for expanding access and services to new domestic and international markets.

2. ***Mode Switching: Logistics and Market Share Models.*** Additional tools are necessary to assess mode switching (e.g., truck to rail). *Logistics Cost Models* predict how shippers respond to changes in the costs of modal and service alternatives, including direct transportation expenses plus inventory costs (that are calculated on the basis of freight lot size and modal service profiles). They balance the benefits of travel time, cost, and reliability by commodity, and they depend on logistic cost factors derived from transportation and industry sources. *Market Share Models* are an alternative predictor of freight modal choices. They forecast modal traffic diversions in response to changes in services and performance, based on either a) statistical correlation between modal performance factors and observed traffic capture, or b) stated-preference interviews with freight

transportation buyers about tradeoffs they would make if faced with hypothetical choices.

(C) Economic Impacts

Given changes in freight transportation system use and performance, economic tools are applied to assess the economic impact of changing costs and revenues for the full-range of industry sectors within the economy. This is represented by the third tier box in Figure 2.4, which references both changes in dollar (cost and income) flows and economic growth responses. The analysis of impacts on the economy can involve up to three types of tools that can be used together:

- *Travel Benefit Calculations* estimate the dollar value of project benefits associated with use of the facilities. *Travel Benefit Calculations* focus on travel time, cost, reliability, and safety changes for vehicles using the facilities. This is commonly done as part of traditional benefit/cost models for highway and airport projects, though their treatment of the value of time delay and reliability for freight is typically cursory or incomplete (since they are designed primarily to focus on passenger travel). Specialized tools and studies exist to fill that gap. *Business Process Models*, including *inventory or supply chain models*, estimate how freight transportation costs, reliability and delivery times together affect total business operating costs and decisions concerning how distribution centers are located and how inventory levels are set. These models supplement or replace the above-cited travel benefit calculations by providing more a complete calculation of impacts on business cost.
- *Business Market Access Models* estimate how changes in access of business delivery markets to intermodal rail, airports, and marine ports can affect regional industry growth through increases in market size and scale economies. These tools complement the user benefit calculations by generating estimates of access impacts on business growth that are beyond the cost savings impacts for existing activities and flow patterns.
- *Economic Simulation/Forecasting Models* estimate how changes in the flow of income and costs among industries lead to broader impacts on economic growth. *Input-Output Models* trace the flow of income among industries and calculate how changes in one industry affect growth in the rest of the economy. *Simulation Models* (including Computable General Equilibrium and Structural Simulation models) also calculate the effects of changes in industry cost competitiveness on economic growth. Both types of models can be regional, multiregional, or national in scope. *International Trade Models* forecast further effects of transportation costs on imports and exports.

(D) Decision Support

The previously-described tools for analysis of economic impacts provide information on impacts at several different levels – in terms of: 1) cost savings for affected businesses, 2) business productivity enhancement, 3) business expansion and associated corporate income growth, and 4) personal income for workers. These concepts all represent elements of "Value Added" or "Gross Domestic Product." So while they differ in their breadth of coverage, any of them can be used to represent economic benefits. However, these economic impact measures are highly overlapping, so only one can be used at any one time to portray economic benefits.

In addition, there can be other benefits that may not directly affect the flow of dollars in the economy, such as environmental improvement and personal time savings that can also be included in various approaches to benefit-cost accounting.[3]

In general, there are four primary types of tools that can be used to represent project benefits relative to costs. They represent different viewpoints or considerations in decision-making, which makes them differ in their portrayal of economic benefits and their inclusion (or exclusion) of environmental, personal and social factors.

- ***Benefit-Cost Analysis*** portrays the sum of benefits accruing to all parties over time, relative to the stream of all project costs. All benefits and costs are expressed in monetary terms and are measured as the net present value. This makes it possible to compare projects involving different timing and costs, but it ignores the incidence of how costs and benefits are distributed.
- ***Cost-Effectiveness Analysis*** portrays the sum of benefits in terms of monetary or non-monetary metrics (e.g., tons of pollution emissions) which are then compared to total project cost. This allows projects to be rated in terms of effectiveness per dollar in achievement of pre-selected environmental or transportation improvement goals.
- ***Equity Impact Analysis*** portrays projects in terms of how the distribution or incidence of benefits compares to the distribution or incidence of project costs. The comparison is usually in terms of 1) public/private sectors, 2) households and industries, 3) socioeconomic population groups, or 4) regions of the country.
- ***Multiple Criteria Analysis*** rates projects in terms of their effectiveness in achieving a wide variety of economic, social, environmental, and other public policy goals. Projects are typically given qualitative ratings, and the weights are applied to calculate a composite total score for each project.

## 2.7 Use of Results

This guide is intended to lay out a consistent process that can be used for evaluating the economic benefits and costs of large-scale capital projects that are focused on freight movement. However, benefit measures and decision support tools need to be

3 As previously noted, environmental impacts related to large-scale transportation project investments have been addressed in other studies and are excluded from this report to maintain a focus on non-environmental economic effects.

selected and applied in a way that covers the underlying motivations for any specific project. The motivations may include:

- Reduce congestion. To improve air quality and reduce transportation costs;
- Enhance safety. To improve local quality of life and save costs;
- Expand system capacity. To enhance investment in economic income growth;
- Improve system performance. To enhance productivity and competitiveness by reducing costs and expanding access; and
- Enhance modal or port competition. To reduce vulnerability to loss; also to reduce costs and expand access.

The relevant *benefit measures* may then include:

- Vehicle Operating Cost Savings from delay reduction;
- Driver and Passenger Time Delay cost savings;
- Accident Reduction cost savings;
- User Logistics/Production cost savings;
- Personal Time Savings; and
- Net Inward Investment (reduction in leakage of money to outside areas).

Missing from this list are the likely social and environmental benefits. These may be large and critical elements of the ultimate project evaluation. Given the current state-of-the-practice methods, however, social benefits are often difficult to quantify and analytical models already exist for evaluating environmental benefits, so these metrics are not included in this framework. However, even within this framework, there are various ways to incorporate and present the above (bulleted) benefit measures in economic terms. They are shown and discussed later, in Chapter 7.

# 3 Step 1: Define Project Type

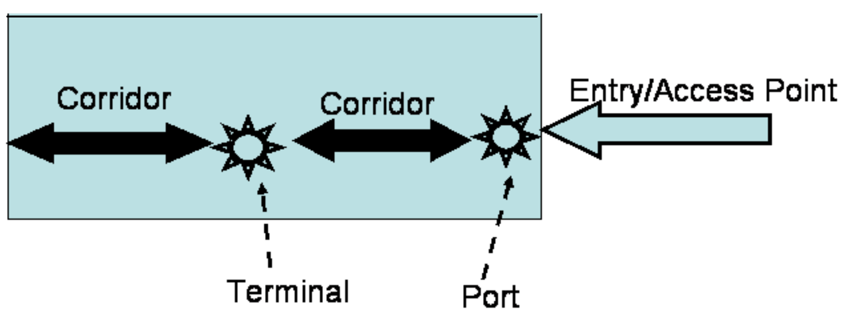
This chapter describes the first step in the analysis framework, which is classification of the project type. The project classification is a critical first step because it determines the applicable evaluation criteria and impact measures – including the types of direct transportation impacts (for Step 3), the types of reliant industries and other affected sectors of the economy (for Step 4), and the geography of the analysis (local or nationwide impacts) to be evaluated (for Step 5).

## 3.1 Functional Activities

The first dimension of the project classification is concerned with the type of transportation facility and its spatial characteristic. There are three major types of facility locations of interest to this framework. They are defined below and illustrated in Figure 3.1:

- *Corridor* – Typically either highway or rail corridors (or both) but could also include a short-sea shipping route or air travel route.
- *Terminal Facility* – Site-specific facilities include seaports, airports, intermodal terminals, etc. Terminals are points of transfer among and between modes, or redistribution along routes. They can be new facilities or expanding the capacity and efficiency of existing facilities.
- *Entry/Access Point* – These are border gateways, though this could also include foreign trade zones, national gateways, or regional distribution centers. As such, they may also be located at seaports or airports.

**Figure 3.1 Types of Project Facilities**




This classification will help identify the types of users and the general geographic or spatial scope of the analysis. It is important to determine if the transportation impacts of the project are able to be captured by modeling or analyzing the project influence within a regional context or whether a broader national or international network system context is needed in order to fully capture the impact of the project. A network system analysis is typically required when evaluating rail and port investments and may be warranted for specific contexts of highway corridor improvements.

While it is difficult to provide generalized guidance on how large an area should be included in the transportation impact analysis, the key considerations include: 1) what are the end-to-end origins and destinations of trips that dominate the use of the facility? and 2) do the travel performance changes within the local geography persist and ultimately translate into meaningful travel savings for shippers? If the project proponents give explicit consideration to these questions, they will be less likely to miss benefits.

## 3.2 Transportation Improvement Categories

The next part is to classify proposed projects by their primary transportation objectives (i.e., the way in which they are expected to improve transportation system performance). So while projects may have transportation, economic, environmental, or political motivations, their primary transportation objectives generally fall within at least one of the following four improvement categories:

- *Link capacity expansion.* Expanding capacity for the throughput of vehicles, containers, or freight (volume or tonnage) that a highway corridor or rail line can process within given performance standards. This can also lead to speed, cost, or other performance improvements at demand levels that are below the link capacity limit.
- *Terminal capacity expansion.* Expanding capacity of throughput of vehicles, containers, or freight (volume or tonnage) that a terminal can process within given performance standards. This can also lead to speed, cost, or other performance improvements at demand levels that are below the terminal capacity limit.
- *Operational improvements*. Enhancing the speed, reliability, safety, or cost involved in use of the link or terminal for any given demand level, without necessarily changing the physical infrastructure capacity.
- *Connectivity*. Improving the speed and reliability of movement between any two points (links or nodes) through reconfiguration of a network. This can be accomplished by means of new or dramatically improved links for movement between two points, or by means of new forms of interchange between two modes or systems of freight movement.

The four major categories of transportation improvement are shown in Table 3.1, along with examples of the range of project actions (investments) that fall within each of these four categories. Note that neither the improvement categories nor the list of project actions makes any distinction between new facilities or existing facilities.

Rather, the table instead focuses on the affected mode and the type of action taken to change capacity or performance. The third column indicates the primary modes that may be associated with a particular type of investment. Understanding which modes will be affected is important for determining the analytical models and methodologies needed later for Step 3.

**Table 3.1 Examples of Projects by Category of Transportation Improvement**

| Improvement Category | Project Action | Mode |
|---|---|---|
| **Capacity expansion – link** | Add general public lanes | Highway |
| | Add truck-only lanes | Highway |
| | Add track | Rail |
| | Upgrade track (speed or weight) | Rail |
| | Upgrade/eliminate grade crossing | Rail/Highway |
| | Upgrade locks/dams | Water |
| | Navigable waterway improvement | Water |
| | Tunnel upgrades | Rail |
| | Correct design deficiencies | All |
| **Capacity expansion – terminal** | Channel deepening – harbor | Water |
| | Air draft improvement | Water |
| | Added lift capacity | Rail/Water |
| | Added terminal storage capacity | Rail/Water |
| | Added gate capacity | Rail/Water |
| **Operational improvements** | Roadway geometrics | Highway |
| | Track alignments | Rail |
| | Signalization improvements | Highway |
| | Electronic control | Rail |
| | Intelligent transportation systems | All |
| | Information systems – scheduling/cargo visibility | All |
| | LCV upgrades | Highway |
| | Hours of operation | All |
| **Connectivity** | Intermodal connector improvements | All |
| | On-dock/near-dock rail | Rail/Water |
| | Gap closure | Rail/Highway |
| | Short haul rail | Rail |

# 3.3 Transportation Benefit and Metrics

**Freight Vehicle Movement.** For each type of project action, there are corresponding benefits for goods movement that can be measured. The five major types direct transportation benefits are:

1. *Faster average travel time*, due either to facility design enhancement, capacity expansion and/or reduction in congestion-induced queuing;
2. *Lower travel cost*, due to improved productivity of the transportation system, from improved cycling of vehicles or railcars, or the ability to handle larger loads (including double-stacked containers, larger vessels or heavier vehicles;
3. *Higher reliability* in delivery times, due to reduction in the frequency or severity of traffic incidents or to reduction in vehicular congestion;
4. *Cargo capacity* in terms of capability to serve growth in freight demand without degraded performance; and
5. *Improved safety* due to design improvements and reduction in congestion, queuing or weaving of vehicles.

Table 3.2 on the next page shows, for each type of project, the corresponding types of transportation benefits and key metrics for portraying those benefits. This is meant to be a generally comprehensive list so that analysts can identify the choice of analytical methods for a specific project type. However, it is important to note that these are just the "first order" direct benefits for freight transportation movement that occur as a direct result of the various types of projects, and do not reflect the broader industry and economy effects described in Step 4 of the analytical framework. They accrue to freight vehicle movement (where a "vehicle" may be a truck, train, boat or aircraft), thus they are experienced first by the vehicle owners and operators.

**Direct Shipper Benefits.** While the first order impacts are experienced by freight vehicle operators and owners, it is freight shippers who ultimately realize the transportation efficiency benefits (for all types of projects) as business productivity enhancements. That results from:

- Greater *system throughput* (volume moving per day);
- Greater *operating efficiency* (cost per unit of throughput); and
- Tighter *scheduling* (allowed by faster times and greater time reliability).

**Cross-Modal Transportation Benefits.** There are also transportation system benefits and beneficiaries that are not listed in Table 3.2. These generally involve *cross-modal benefits*, such as congestion reduction benefits (travel time, reliability, and safety improvement) for passenger vehicles that benefit when some freight movement is shifted from truck to short-haul or medium-haul rail service.

**Table 3.2 Transportation Benefits and Metrics by Project Type**

| Project Type | Mode | Transportation Benefits | Metrics |
|---|---|---|---|
| Add general purpose lanes | Highway | Congestion – travel time savings<br>Reliability – reduced incident impact<br>Potential accident reduction | Travel time<br>Non-recurrent delay<br>Accidents |
| Add truck-only lanes | Highway | Congestion – travel time savings<br>Reliability – reduced incident impact<br>Potential accident reduction | Travel time<br>Non-recurrent delay<br>Accidents |
| Add track/new link | Rail/Hwy | Congestion – time savings/car cycling<br>Potential reliability – queue impact<br>Diversion to rail reduces congestion | Travel time, cycle time<br>On time performance<br>Volume, travel time |
| Upgrade track (speed or weight) | Rail | Improved travel time, railcar cycle time<br>Potential reliability<br>Potential safety | New weight/speed<br>On time performance<br>Accidents |
| Upgrade/eliminate grade crossing | Rail/Hwy | Potential speed/travel time savings<br>Accident reduction – reliability Savings | Average speed<br>Accidents |
| Upgrade locks | Water | Improve travel time | Travel time |
| Waterway improvement | Water | Increased vessel drafts reduces costs<br>Potential safety/incident and reliability | Cost per unit (ton or TEU)<br>Accidents |
| Tunnel upgrades | Rail | Double-stack potential – car cycle time | Direct cost |
| Correct design deficiencies | All | Local congestion/travel time<br>Reliability – reduced incident impact<br>Accident reduction – reliability savings | Average speed<br>Incident delay<br>Accidents |
| Channel deepening | Water | Increased vessel drafts reduces costs | Cost per unit (ton or TEU) |
| Air Draft improved | Water | Increased vessel drafts reduces costs | Cost per unit (ton or TEU) |
| Added lift capacity | All | Increased throughput – delivery speed | Throughput per acre |
| Terminal capacity | All | Increased throughput – delivery speed | Throughput per acre |
| Gate capacity | All | Increased throughput – delivery speed | Throughput per acre |
| Roadway geometrics | Highway | Local congestion<br>Reliability – reduced incident impact<br>Accident reduction – reliability savings | Average speed<br>Incident delay<br>Accidents |
| Track alignments | Rail | Local congestion<br>Reliability – reduced incident impact<br>Accident reduction – reliability Savings | Average speed<br>On time performance<br>Accidents |
| Signalization, electronic control | Highway<br>Rail | Local congestion – travel time<br>Local delay – travel time | Travel time, network model<br>Travel time delay |
| ITS | All | Congestion benefits – time savings<br>Reliability, incident management | Travel time, network model<br>Incident delay |
| LCV upgrades | Highway | Productivity – cost savings | Unit costs |
| Hours of operation | All | Congestion benefits – time savings | Travel time |
| Intermodal connectors | All | Congestion benefits – time savings<br>reliability – not related to incidents | Travel time |
| Rail on/near dock | Rail/Water | No direct benefit, secondary only | Cost per unit |
| Gap closure | Rail/Hwy | Congestion benefits – time savings<br>Reliability – not related to incidents | Travel time |
| Short-haul rail | Rail | Potential speed or capacity improvements<br>Potential reliability | Travel time<br>Throughput |

**Result.** The end product of Step 1 should be a classification of proposed projects by their a) mode and functional activities, b) form of improvement, c) mix of project actions, and d) associated metrics for assessing transportation benefits.

# 4 Step 2: Define Evaluation Issues

This chapter describes the second step in the analysis framework, which is the identification of evaluation issues. This step starts with the transportation benefits identified in the prior task, and moves on to identify the fundamental economic effects and broader (social, environmental, and public policy) objectives motivating the project. These broader issues are critical because they represent the most fundamental criteria upon which projects must be evaluated.

It is important to note that there is no direct or automatic connection between the type of project identified in Step 1 and the relevant evaluation issues considered here in Step 2. Both are important for different reasons. It is important to classify the project type in Step 1 so that direct transportation benefits can be appropriately measured.

## 4.1 Identifying Issues and Audiences

**Response to a Problem.** While the transportation benefits listed in Step 1 focused on efficiency, that is too narrow. Rather, we recognize that most large-scale freight projects are usually proposed as a response to a significant problem that is either at hand or imminently expected for the future. The problem is typically that an existing facility or set of facilities is seen as:

- *Constrained* from meeting future growth needs;
- Becoming *uncompetitive* in meeting evolving customer needs; or
- Where *external impacts* (environmental or safety effects) are growing.

Therefore some combination of capacity or performance enhancement is seen as necessary to eliminate, reduce, or offset the problem.

**Underlying Motivation (Concerns).** The motivation for project proponents (who see a problem requiring action) is usually centered on concerns about the financial viability and competitiveness of the freight transportation facilities in the face of changing demand, or else the environmental consequences of those changes. The metrics for underlying motivation may thus be classified into the following four categories of concerns:

- Ability of the freight transportation facilities to accommodate the *growth in activity* of shippers that depend on them;

- Ability of the freight transportation facilities to accommodate *changing shipping requirements* of the firms that generate their demand (including cargo size/weight features, delivery schedules, origin-destination patterns and vehicle vessel types);
- Ability of the freight transportation facilities to provide for the growth and changing shipping requirements, while maintaining *cost competitive* service for shippers that depend on them; and
- Ability of the freight transportation facilities to make the above-mentioned adjustments in activity level, shipping forms and costs without imposing *adverse impacts on surrounding communities* (associated with land takings, and vehicle activity volumes at both port/terminal locations and ground transportation routes serving them).

**Ultimate Stakes.** The ultimate stakes for proponents include both the economic and non-economic qualities of their lives, their companies, or their communities/regions. The appropriate benefit metrics depend on the stakeholders. Some audiences would be satisfied with knowing the improvements to the usual transportation metrics (e.g., travel time and reliability, accidents, operating costs) and logistics effects. Not all analyses need to estimate changes in GDP, income or jobs. Ultimately, many stakeholders will want to have estimates of the following elements of economic and environmental impact:

- Jobs and associated income for companies and workers that provide services at or through the freight transportation facilities;
- Jobs and associated income for companies and workers that are not directly associated with the freight transportation facilities, but depend on them for cargo movement (needed for incoming materials and outgoing product deliveries);
- Jobs and income for companies and workers elsewhere in the economy that indirectly benefit from the economic health and income generated by the freight transportation facilities and their users; and
- Environment and safety for residents of communities abutting the port/ terminal facilities and transportation corridors serving them.

When considering these "bottom line" metrics, it becomes important to also evaluate various factors affecting their spatial pattern of impact and distribution of benefits, including the following:

- National economic growth/productivity, security, resiliency in events of disaster or trade disruption accommodating growth, and international trade (all projects);
- Benefits to a particular mode, carrier or industry-specific targets (all projects);
- Local or regional income and economic development; and
- Allocation of costs and beneficiaries among sectors of the economy.

Thus, the framework is intended to capture all transportation effects, national scale of goods movement, and impacts to industries. The final steps also analyze ultimate effects on income generation (value added) in the economy viewed from both national level and local level perspectives, as well as for subsets of the economy (such as shippers, carriers and related industries) if needed.

## 4.2 National and Local Issues

It is necessary to examine economic effects from both national and more local (community, region, or state) levels for several reasons. One is that the Federal government has an interest in national-level economic growth but also in regional development that supports efficient national growth. There are many Federal programs that support the economic development of regions and local areas that are in economic distress. Such programs support the creation of jobs in areas of high unemployment and under-employment. In addition, there is a Federal role in providing technical assistance to local areas.

Since national and state/local interests are often intertwined, it becomes important to estimate economic benefits at national and state/ local levels. Such analysis can also serve as a basis for identifying the distribution of benefits from large-scale projects and hence issues to consider in cost and benefit sharing among jurisdictions.

## 4.3 Stakeholders: Incidence of Benefits and Costs

Each of the various combinations of project actions and modal facilities directly translates into a different set of public and private stakeholders. This includes both stakeholders incurring project costs and stakeholders reaping project benefits.

**Incidence of Costs.** To assess the incidence of project costs (i.e., who ultimately funds the improvements), it is useful to distinguish the parties responsible for both capital and operating costs, which may be borne by Federal, state, and local governments, as well as the private sector. Furthermore, many freight projects directly transfer some of these costs (especially operating costs) to other parties via tolls or fees. In determining the incidence of costs, ownership of the facility(ies) in question can be confusing and may be ultimately provide a poor indicator of who is paying for the capital investment and its operation.

**Incidence of Benefits.** While ownership of freight transportation facilities tends to vary systematically by mode and facility type, the beneficiaries are generally shippers regardless of the modes being used. In general, freight carriers (or more correctly, those who own and operate freight vehicles) experience the travel time and operating cost savings from transportation improvements, but the shippers who pay for and rely on the freight transportation system end up ultimately realizing most benefits. This is true for several reasons.

For trucking, studies by the Bureau of Transportation Statistics show that nearly half of all freight spending is for in-house truck fleets that are owned and operated by the shippers themselves – manufacturers, wholesalers, retailers, agricultural producers, and service companies. Second, even when for-hire motor carriers are used, transportation cost and time savings tend to be passed on to the shippers in the long run, and it is also the shippers who typically realize the additional benefits of schedule reliability improvements. Third, the distinction between carriers and shippers is becoming further clouded as more firms adopt integrated supply chain logistics, and as freight carriers take on growing roles in providing inventory management and other logistics services for their customers.

For other (non-truck) modes of freight transport, a variant of the same story applies. Some shippers own their own containers for rail or sea shipping. Others own their own railcars. Most other shippers are reliant on for-hire carriers or freight forwarders for moving their air freight, marine freight or rail freight, though reliance on integrated logistics is also rising for these other modes of freight movement.

The bottom line, then, is that the distinction between carriers and shippers is becoming increasingly elusive. That distinction is also not particularly relevant for this guidebook. Rather, it is more useful to recognize that the real beneficiary of freight transportation improvements are manufacturers, services and trade firms that generate the freight demand and rely on freight movement to provide their products and services. And the ultimate beneficiaries of improved productivity for these shippers are the workers who gain additional jobs and income as well as the customers who gain from lower cost and higher quality products and services. Other ultimate beneficiaries are passenger vehicle drivers and passengers who can gain when roadway congestion is reduced and there is less truck-car interaction or competition for road space.

**Implications for Evaluation.** The incidence of ownership and cost responsibility differs systematically by type of facility and mode, while incidence of benefit tends to be distributed among sectors of the economy that are either directly or indirectly benefiting from those facilities or the worker income that they generate.

## 4.4 Alternative Impact Metrics

The appropriate measurements of benefits from freight transportation projects start with estimation of initial direct benefits in terms changes in efficiency of transportation (e.g., travel time, reliability). This proceeds to intermediate measures of business activity, such as productivity, average wages, or capital investment. Ultimately, most direct and intermediate benefits show up as changes in regional or national economic activity and thus are usually expressed as economic metrics such as changes in gross regional or national product (which reflects the sum of worker income and net corporate earnings that may be paid out to owners or reinvested in further business expansion), jobs and personal income to workers. Depending on the purpose of the project and the preferences of decision-makers, the analytic framework can produce some or all of these metrics as a final product for decision-support. However, the goal of this framework is to proceed all the way to calculation of aggregate measures of regional and economic impact along with the sectoral/firm economic benefits and the transportation impacts from which they derive.

These measures should reflect three different dimensions:

- *Spatial levels.* both national and also state or regional level perspectives;
- *Benefit measures.* Narrow transport efficiency, and income growth benefits for businesses that use or otherwise rely on the facilities (shippers), and broader effects on the rest of the economy; and
- *Sectors of the economy.* Including both import/export international trade and domestic business sectors.

Whatever metrics are used, however, the ultimate set of benefits may not provide a clear cut up or down measure of success. Significant improvements to the infrastructure supporting international trade, for example, have helped to move a great deal of U.S.-based manufacturing off-shore. This has led to lower prices for consumer goods (a benefit that appears as a net increase in personal income), but it has also led to significant job loss and lower wages. This contradiction across metrics may also be important when it exists for the same metric: a freight improvement may increase one region's gross regional product at the expense of its neighboring regions.

# 5 Step 3: Transportation Impact Tools

This chapter describes the third step in the analysis framework, which is the analysis of transportation impacts. Given the type of project (as described in Step 1), the transportation analysis estimates the effects in terms of modal performance and cross-modal diversion, and the implications of those changes for shipper logistics. This analysis provides a basis for the economic analysis in the subsequent step. It is organized into five parts:

1. Initial screening to define transportation efficiency benefit;
2. Mode-specific performance analysis for freight;
3. Modal diversion analysis for freight;
4. Treatment of carrier and shipper cost; and
5. Final analysis and presentation of results.

## 5.1 Phase 1. Identification of Transportation Efficiency Benefit

The classification of project types in Step 1 (Chapter 3) leads to an initial identification of the relevant types of transportation impacts and their measurement. In general, these can be classified into five types of impacts:

1. *Travel time improvements.* Savings in the average travel time for existing and projected shipments given their origins and destinations. This reflects changes in average speed and schedule frequency of service, and also accounts for effects of predictable congestion bottlenecks and transfer delays. Improvements in travel time are also used to evaluate improvement in shipper access to markets (for buyers/suppliers), border crossings, and other modal facilities (seaports, airports, intermodal rail terminals).
2. *Cost savings benefits.* The net reduction in freight transportation cost associated with transportation system performance improvements. Typically methods of estimating cost savings account for changes in cost of driver time, vehicle (or vessel) operating cost implications, and changes in effective vehicle capacity (cargo volume).

3. *Reliability benefits.* The reduction in non-recurring delays associated with improvements that reduce the frequency of traffic accidents, vehicle breakdowns, and other non-predictable situations that lead to variation in travel time. These benefits can be measured in different ways depending on how the improved reliability is achieved, and who will benefit from among carriers and users. Examples of typical metrics would include hours of non-recurrent delay (which may be calculated through regression models that relate non-recurrent delay to traffic volumes, roadway classification, or other network characteristics), buffer time, or on-time performance percentage.

4. *Cargo capacity benefits.* These benefits are most commonly related to projects that increase net effective capacity and throughput at seaports, airports, or intermodal terminals, in light of existing capacity constraints.

5. *Safety benefits.* These can represent an environmental externality, but for carriers and shipper, they may also translate into changes in business costs for breakage, vehicle repair, insurance, and/or employee down time.

For any given project analysis, some combination of these direct transportation impacts will be measured and in most cases, the nature of impacts, lack of data or availability of models will result in not measuring all five benefit categories. There are two sets of tools that can be applied to predict and calculate the magnitude of major impacts of these types. They are 1) mode-specific performance models, and 2) cross-modal diversion models. Using these models (discussed in Section 5.2), it is possible to calculate how travel times, vehicle costs, reliability, capacity, and safety levels can be affected by a proposed project. Different models may be necessary depending on the specific modes involved.

The types of metrics that can be developed by applying modal performance and diversion models are summarized in Table 5.1. It is important to note that impacts are distinguished by mode of freight travel, and the analysis may need to also include passenger modes that share facilities (highways, tracks, harbors, airports) with the freight modes. In addition, it should be noted that some of these effects (such as changes in cargo tons, vehicle volumes, time and costs) come directly from transportation models, while others (such as market delivery and terminal access times) need to be derived by the analyst using available model statistics.

**Table 5.1 Typical Data Used to Describe Transportation Characteristics/ Impacts of Large-Scale Projects**

| Facility | Road | Road | Rail | Air | Water |
|---|---|---|---|---|---|
| Mode | Car/Lt.Truck | Truck | Freight Train | Aircraft | Ship |
| Peak Capacity | x | x | x | x | x |
| Vehicle-Trips Weekday | x | x | x | x | x |
| Percent of Time Congested | x | x | x | x | x |
| Percent of Time at Capacity | x | x | x | x | x |
| Passengers per Vehicle-trip | x | x | x | x | x |
| Freight Tons per Vehicle-trip | x | x | x | x | x |
| Freight Volume per Vehicle-trip | x | x | x | x | x |
| Form of Freight (Mix) | x | x | x | x | x |
| Total Shipment Distance (avg) | x | x | x | x | x |
| Local Portion of Trip Ends | x | x | x | x | x |
| VMT Weekday | x | x | x | x | x |
| VHT Weekday | x | x | x | x | x |
| Fatality Accident | x | x | x | x | x |
| Pers Injury | x | x | x | x | x |
| Prop Damage | x | x | x | x | x |
| Market Size (Access Reach) | x | x | x | x | x |
| Avg Terminal Access Time | x | x | x | x | x |

**Form of freight distinguishes bulk, break bulk, container, truckload, and less-than-truckload shipments*

# 5.2 Mode-Specific Performance Analysis

**Types of Models.** For each mode of transportation (highway, rail, air and marine), there are models that analyze the demand for use of routes and terminals, the functional capacity of those routes and terminals, and resulting changes in their performance when faced with changing patterns of demand. The utility of this class of models for impact analysis is their capability to simulate how improvements to network or terminal facilities can improve performance in terms of increasing speeds, reducing bottlenecks and schedule delays, reducing operating costs, and improving safety.

The models for highway and rail systems tend to focus on network performance, since the major capacity constraints for those modes are the travel network links. Likewise, the models for air and marine transportation tend to focus on terminal or port performance, since they are the major capacity constraint for those modes. As a practical matter, highway network models are more available than models for the other modes. Models for rail, air-freight, and water-side maritime operations are rare (see Section 10 for further discussion).

Depending on the type of project, all of the various modes can be relevant for analysis, and any of the network or terminal performance models may be relevant for use in project evaluation. However, in the context of large-scale freight projects, it is most useful for this guide to focus on special challenges posed by projects that involve multiple modes of freight. In fact, nearly all large-scale freight projects are multimodal and involve some combination of rail-truck, port-rail or port-truck or airport-truck interface. All of the case studies described in Chapter 8 also illustrate these same modal combinations and interactions.

Thus, in the interest of brevity, we have relegated the overview of network and terminal performance models to the Chapter 10 Toolbox. That chapter discusses the availability of individual performance models for highway, rail, aviation, and marine transportation. The rest of this section focuses just on the most common problems facing multimodal freight facilities, which focus most on network performance for railroads and reliability for road systems.

*See the Chapter 10 Toolbox for an overview on available network and terminal performance models for all modes.*

**Major Challenges for Network Model Analysis.** A critical question in this type of analysis is whether local congestion impacts have any benefit to users other than the limited effect they have on carrier costs in a local market. The analysis needs to first determine how the effects are translated into long-haul travel time savings. Examining the origin-destination (O-D) characteristics of freight movement using the facility is a way to begin to gauge the extent of the network's influence. For example, the proposed Cross Harbor freight rail tunnel in New York City (see Chapter 8 case study) would impact freight rail trips originating in Atlanta and Chicago. Also, facility-related trips that require intermodal linkages add another layer of complexity in understanding end-to-end goods movement.

Another issue is idiosyncrasies from network reconfiguration. This issue focuses on whether a local congestion hot spot once alleviated would lead to major re-routing of traffic in a larger network. This can be detected by a standard travel network model as long as the area is large enough. The other issue is whether cleaning up one bottleneck just creates a new bottleneck downstream. Some have argued this was the case with the Alameda Corridor. There are new techniques being developed that prioritize bottlenecks based on overall system performance impacts that may be helpful in this regard.

**Traffic Simulation and Highway Network Analysis**

Most of the examples provided in this guidebook conduct highway network impact analysis using travel demand models (these are the most commonly encountered tools for evaluating travel time savings and related network effects). However, in the case of projects that deal with freight bottlenecks, traffic simulation models may be a necessary tool because they take into account queuing behavior that can build over time at a bottleneck. This type of queuing will affect reliability and overall travel time over long periods of time as capacity of the system is significantly exceeded and may provide an indication that the facility is saturated and cannot accommodate more growth. The implication this has for modal diversion, diversion of traffic to another geographic area, or increased overall cost of freight movement may be far greater in these situations than would be indicated from the results of a travel demand model. While traffic simulation can be expensive, there are simple simulation tools that are being used to provide some initial indication of this type of bottleneck. In cases where the investments are significant and the bottleneck is bad enough, use of more sophisticated simulation tools may be warranted.

**Special Issues for Railroad Networks.** Special challenges are involved in examining railroad network performance. Since highway facilities are publicly owned, the responsibility for analyzing their performance falls to state and metropolitan transportation agencies across the nation. As a result, the available tools for evaluating highway facilities, including their corridors serving marine and air ports, are commonly available. However, railroad facilities are usually privately owned, and thus most public agencies have far less familiarity with data and tools for evaluating rail system performance. That also makes it particularly critical to improve methods for assessing the public benefit for improving freight rail facilities. Accordingly, it is useful to focus particular attention on challenges for evaluating freight rail networks serving urban ports, terminals, and intermodal truck-rail facilities.

Railroad simulation models are used to evaluate track configurations, signal systems, and operating plans. These models generally mimic train dispatcher logic and are used to evaluate infrastructure and/or operational changes. A common use is to evaluate the running of passenger and freight trains over the same track to identify bottlenecks and capacity constraints. Most models produce schedules, string line displays[4], and various performance measures permitting comparison of alternative scenarios. These simulation models do not provide a direct measurement of capacity, but are used to identify potential capacity problems.

This class of models is designed to simulate the decisions made by train dispatchers. They do not, in general, contain optimization or other decision-making components. They do follow a set of fixed rules governing train priorities and a train performance calculator to model train physics (acceleration and deceleration). By providing track configuration, signal systems, and operating plans as input, an experienced user can evaluate the outputs to determine bottlenecks and conflicts. Adjustments are made to the inputs to resolve these conflicts (typically adding and/or lengthening a siding, double tracking, or adjusting train schedules).

In addition to the simulation models, there has been recent interest in developing parametric rail capacity models. These models develop capacity curves for various operating characteristics and, based on the operating plan profile of a rail line, identify areas with capacity constraints. They are much less data intensive than the simulation models. Parametric models can help identify capacity "hot spots," which would then need to be further explored with a simulation model.[5]

Railroad operation and impact models tend to be very data and labor intensive. They are used internally by the railroads and for large scale projects and mission critical analysis. Because of the effort and cost of these specialty models, they are more appropriate for a detailed design phase than a preliminary benefits phase. There is a

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[4] A string line display is a time space diagram where geographic locations (either stations or mileposts) are on the y-axis and times are on the x-axis. Trains can be shown moving in two directions. A key aspect of string line displays is showing where two trains cross, which must be at a siding or other location with multiple tracks.

[5] For a more detailed description of parametric capacity models, see Harold Krueger, *Parametric Modeling in Rail Capacity Planning*, Proceedings of the 1999 Winter Simulation Conference. Also see Federal Railroad Administration, *Parametric Analysis of Railway Line Capacity*, August 1975, Report No. FRA-OPPD-75-1.

need for simpler, sketch planning rail models to answer a few questions at a more general level, such as: 1) how many trains will run through my town? 2) Will this project improve freight rail service? 3) Will other investments be needed to fully achieve the benefits?

**Special Issues for Highway Reliability.** For freight movement, schedules and travel time reliability are important, particularly for time-sensitive shipments that tend to travel via truck or air-truck combination. Methodologies that are being used and developed for transportation analysis have been focused primarily on highway network systems, although there are logistics process models from the industrial engineering/operations research fields that are used in the rail industry to predict the cost implications of reliability changes on production processes.

If reliability is defined as variability of travel time, very few of the methodologies above address true reliability estimation. This topic is currently being addressed for highway networks in NCHRP 7-15 and sketch planning methods may be developed as a result of this work that will prove valuable in the future. Actual variability in travel time may be important for economic impact evaluation for several reasons:

- Carriers may react to travel time variability by planning for mean delay (or some threshold of delay). In this case, knowing the distribution of incident-related delay is as important as knowing the cumulative total incident related delay. The planned-for incident related travel times can be used to estimate carrier costs regardless of average recurrent congestion conditions calculated by traditional planning travel demand models. The same value of time can then be used to begin calculating the economic impact of recurrent congestion.
- Shippers (freight system users or customers) may have a window of on-time performance before intermodal connections are missed and production processes are affected. Knowing how often this window is missed may be important in logistics process models.

Methods that are generally available for reliability analysis of highway networks are not true reliability predictors. Rather, they estimate cumulative incident-related delay, often as a function of volume/capacity ratios. The economic impact of travel time variability is effectively taken into account by valuing incident related delay at a much higher level than recurrent delay. A system that does this explicitly is the benefit-cost component of the ITS Deployment Analysis System (IDAS) developed for the Federal Highway Administration (FHWA), which values non-recurrent delay at three times the value of recurrent delay.

A number of studies have been conducted over the years that attempt to estimate the impacts of incidents, but since they employed techniques that do not directly predict incidents the results are limited when analyzing the effects of system improvements.[6] Most of these techniques are based on traffic engineering methods and often rely on microscopic simulation methods.

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[6] Most travel demand network models are based on "average" travel conditions and typically do not adequately capture the effects of incidents.

A useful approach for estimating travel time variability for highway mode is also included in the FHWA's 1998 study on Sketch Methods for Estimating Incident-Related Impacts. The method computes vehicle-hours of incident-related delay for freeway corridors based on defined characteristics including: number of lanes, free-flow speeds, V/C ratios, accident rates, incident duration factors, and presence of recurrent bottlenecks. The method was developed using a combination of macroscopic simulation methods, queue analysis methods, and stochastic procedures, and it represented a precursor to IDAS. As applied in several of the economic impact case studies presented in Chapter 8, the lookup tables of non-recurrent delay impacts have been used as a post-processor with travel demand models.

It should be noted that none of these methods takes into account the performance benefits of truck-auto separations and truck tollways.

**Safety Impacts.** Though the motivation for large-scale freight projects is commonly more efficient movement of goods, another motivation and benefit can be improved safety and reduced accidents. This is particularly important when projects help to reduce intermodal interactions (such as reduction in road-rail grade crossings, or diversion from congested areas). For example, freight rail improvement projects that help divert truck traffic to the rail system can result in fewer highway accidents. Or, reducing at-grade rail-highway crossings can also improve safety at the same time as it improves efficiency (as illustrated in Chapter 8 case studies, including the Alameda Corridor and Chicago *CREATE*). Relevant issues regarding the modeling of safety benefits include:

- Statistical methods to estimate changes in accidents of varying severity;
- Numerous user benefits models have algorithms that estimate accidents based on factors such as facility class, travel speed, capacity, and traffic volume; and
- Accident impacts typically arise in the context of highway network analyses when reductions in truck VMT occur or improvements are made to the functional class or geometry of a roadway.

Despite these methods, there are few other predictive models available and most other modes are usually not evaluated in terms of accidents for large-scale projects. Consequently, few analyses contain detailed evaluations of accident reductions.

## 5.3 Modal Diversion Analysis

**Types of Cross-Mode Substitutions.** Any improvement to facilities and services of one transportation mode can have implications on demand and performance of other modes. This can occur insofar as there are substitutions between air and sea for overseas shipping or between truck and rail for domestic surface shipping. Of course, substitution is also possible between other modal combinations for specific short-, medium-, and long-distance shipping. This can include short sea barge shipping in place of rail for heavy cargo, or air in place of trucking for container cargo, as well as other combinations.

See the Chapter 10 Toolbox for an overview on available modal diversion and logistics cost models.

Two classes of tools are available for analyzing modal choice and diversion among freight shippers: statistical models of market shares and total logistic cost models. Both calculate how shippers change their mode choices in response to changes in the various service features and costs of modal options (most frequently rail and truck modes). The availability and features of such models are discussed in the Chapter 10 Toolbox. In the interest of brevity, the discussion here illustrates the most common modal diversion issue facing large-scale multimodal freight investments, and that is the impact of rail-related investments on truck and other highway vehicle traffic.

**Truck-Rail Diversion Issues.** Experience suggests that the estimates of net reduction in trucks on the roadways due to rail improvements is often viewed with skepticism by public officials because of the complexity of the issue, the risks involved, and the impacts these estimates have on public benefits. It raises many additional questions. If the public invests in a freight rail line, will the railroad improve service and/or lower costs to attract new business? If so, will the shippers respond by diverting traffic from truck to rail? How will changes in shipper logistics patterns and costs ultimately impact the consumer, who paid for part of the rail improvement through taxes?

A mode choice, or diversion, model for truck and rail choices is used to determine the extent to which mode shares change, given a change in any of the transportation service attributes. Mode choice for freight shipments is based on three primary factors: goods characteristics; modal characteristics; total logistics costs and supply chain design. The factors impact the feasibility of freight rail diversion in different ways:

- *Goods characteristics.* Shipment size, package characteristics, shipment shelf life, shipment value, shipment density; some goods are simply not suited to rail carriage (e.g., pharmaceuticals), while others are not suited to highway carriage (e.g., coal).
- *Modal characteristics.* Capacity, trip time, reliability, equipment availability, customer service and handling quality, modal cost; these characteristics, some of which can be changed through rail freight investment, interact with the goods characteristics to determine the feasibility of movement by rail.
- *Total logistics costs and supply chain design.* Even if the goods are well suited to rail transport, and rail service is available, the design of the logistics chain may be such that trucks provide more economical and dependable service. In cases where truck travel times are significantly faster than rail, the inventory carrying costs of expensive goods, or an environment requiring short lead time, can overcome higher transportation rates.

The importance of modal diversion analysis for major investment projects is that such impacts will also affect carrier costs for both modes and it will change the calculation of cost savings for shippers. The treatment of those costs is discussed next.

# 5.4 Treatment of Carrier and Shipper Costs

The first component of economic analysis of transportation investments requires an assessment of carrier response to transportation improvements. For most analyses, transportation investments will reduce operating costs of carriers by introducing or improving infrastructure (ports, roads, etc.) that carriers use. In many cases, analyses focus on the (positive) impacts of transportation investments relative to "do-nothing" scenarios under which existing infrastructure degrades and/or cannot accommodate expected growth in demand.

**Link Between Carrier and Shipper.** For purposes of discussion, assume that a proposed transportation investment will lower operating costs of carriers by reducing congestion delay. As such, the first component in an economic analysis must focus on the link between a reduction in operating costs for carriers and a reduction in prices that carriers charge (and shippers pay).

There are two extreme cases. In the first, there is a *monopoly carrier* that does not pass along any of the reduction in operating costs in price reductions, thereby, raising its profits by the amount of operating cost reductions. In this case, the national economic impact will be reduced to spending generated by the increase in profits for company owners or shareholders; the local impact will be determined by the proportion of owner/shareholder profits that stay in the local economy. These local and national economic impacts do not necessarily reflect net gains. Calculation of net gains would require comparison of the cost of public investment with private gains by carriers. If the cost of public investment is greater than the private gains, then the net national impact will be negative. If the cost of public investment is less than the private gains, then the net national impact can be expressed as the difference between public and private gains. (Note that in this case, efficiency gains are a product of the investment itself, which has greater benefits than costs, rather than to the behavior of carriers or shippers.)

In the second extreme case, *perfect competition* causes carriers to pass along the entire reduction in operating costs in the form of price reductions for shippers (and receivers). In this case, the national economic impact will be a function of productivity gains to local carriers, which will face higher demand for their products and thus could achieve economies of scale;[7] productivity gains that accrue to freight users, who can now produce a given amount of output for fewer inputs; and any business relocation and economy of scale impacts these productivity gains generate. Local economic impacts will be driven by increased demand and output for carriers and increased business activity associated with lower costs and increased output at existing shipping firms in the local area and any relocation gains that accrue.

It is unlikely that the first of extreme cases occurs very often in the real world. When faced with falling operating costs, even pure monopolies should lower prices (though

[7] Economies of scale effects for carriers and shippers that gain business must be compared with productivity losses at firms in the U.S. that lose business activity.

far less than firms in competitive markets) and increase output (though far less than firms in competitive markets) in order to maximize profits.[8] Firms in perfectly competitive markets will employ marginal cost pricing. Thus, to the extent that transportation improvements reduce marginal (rather than fixed) costs of carrier operations, the reduction in operating costs will be wholly reflected in price reduction to freight users in perfectly competitive markets.

Although the market for freight services is not perfectly competitive in all (geographic) markets, the default assumption in analyses of transportation investments is usually that cost reductions for carriers are passed onto freight users. This assumption is made because of the levels of competition thought to characterize freight markets in the wake of international competition (e.g., between Canadian and American ports) and deregulation efforts in air, rail, and trucking services. Empirically, however, it is difficult to determine a priori the effect of a carrier cost reduction on prices faced by shippers and receivers. However, a recent examination of rail freight rates found that rates vary by rail line/location and commodity being shipped (GAO, 2002). The latter study presented evidence that on some lines, “railroads did not pass on all cost reductions to customers in the form of rate reductions” and concluded, among other things, that a range of factors, including local competition in freight services (rail and non-rail), influences rail freight rates (p. 28).

Given the importance of carrier pricing to estimates of the economic benefits of transportation projects, it is important that analyses include thorough consideration of likely responses of carriers to changes in operating costs brought on by transportation investments. It does not appear, however, that methodologies to address this question have been fully developed and unfortunately, economic models commonly used in large-scale transportation project analyses cannot usually be used to examine the likelihood of or size of price reductions associated with a reduction in operating costs for carriers.

Research on this topic suggests that freight pricing issues can be sensitive to context, so analysts should consider whether the level of competition in freight markets is reasonably competitive before (and after) the project investment. If so, it is likely that the assumption that freight users capture all or most of the benefit of cost reductions for carriers is valid. If the local freight market will not be competitive even after the project investment, analysts must consider how accurately to capture the links between transportation investment, reduction in operating costs for carriers, and prices paid by shippers. Nonetheless, given the long-term impacts associated with freight transportation investments, it is likely that even if cost reductions aren’t immediately passed along to freight users, that over time, shippers and receivers will experience a benefit given the generally competitive freight transportation industry.

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[8] As long as demand is price-sensitive (elastic), then a monopoly with sufficiently reduced operating costs will find it profitable to also reduce its selling prices.

# 5.5 Final Analysis and Presentation of Results

**Multiple Measures and Perspectives.** The final results of the transportation analysis should provide a series of findings that are summarized in Table 5.2. These results must be consistent with three needs:

1. First, analysis should portray how proposed changes in network and terminal facilities will affect *system performance* by mode. That may include changes in average travel times, flow volumes, shipping costs (per ton or TEU), reliability and/or safety. This is represented by the first row in Table 5.2.

2. Second, they must show the *volume of freight* (tons or TEUs) by type that is projected to be subject to these transportation performance improvements. That must account for baseline forecasts and any modal diversion as well as any changes in activity levels due to elimination of capacity constraints. This is represented by the second row in Table 5.2.

3. Third, they must portray how the changes in system performance translate into direct *benefits for freight shippers* who are the users of the freight transportation systems. That may include transport costs or savings passed on by carriers as well as logistics and delivery access impacts. These impacts are represented by the third row in Table 5.2, and they actually form the basis for economic impact modeling as discussed in the next chapter.

There are several other notable elements of Table 5.2. One is that the results are shown by mode. That is needed so that the final analysis of benefits (discussed in Chapter 7) can distinguish the incidence of impacts by mode as well as the associated public-private cost and benefit allocation. Another notable feature is that impacts on shipper cost (given projected freight origin-destination flow patterns) are complemented by separate measures of other changes in system throughput and market access (or connectivity) impacts. All of those other forms of transportation impact can then be assigned additional benefits using procedures described in Chapter 6.

**Table 5.2 Example Portrayal of Findings from Transportation Analysis**

| | Truck | Rail | Air | Sea |
|---|---|---|---|---|
| **System Performance Impacts** | | | | |
| • Increased Vehicle Capacity (TEUs or tons per vehicle) | | | | |
| • Increased Line or Terminal Capacity (Vehicles per hour) | | | | |
| • Increased Schedule Frequency | | | | |
| • Reduction in Recurrent Interchange or Bottleneck Delays | | | | |
| • Reduction in Non-Recurrent Incident Delays | | | | |
| • Improved Safety | | | | |
| **System Throughput Changes** | | | | |
| • Predicted Change in Throughput Volume | | | | |
| **Shipper Impacts** | | | | |
| • Reduced Transport Costs | | | | |
| • Reduced Logistics Costs | | | | |
| • Improved Productivity | | | | |
| • Improved Terminal Access | | | | |
| • Enlarged Delivery Market Area Access | | | | |

# 6 Step 4: Select and Apply Economic Impact Tools

This section describes the general framework for modeling economic impacts of major freight transportation projects. It is organized into five parts:

1. Initial screening to define overall economic benefit;
2. Recognition of industry reorganization effects;
3. Recognition of national and local distinctions;
4. Application of economic models to assess impacts; and
5. Final analysis and presentation of results.

## 6.1 Phase 1 Screening: Overall Economic Benefit

The overall economic benefit of a major freight transportation project is a total dollar value of all time, expense, reliability, safety, and capacity (throughput) impacts. At an initial screening level, it is the total value of the benefit rather than the beneficiary that is most important. However, the measurement needs to be generally complete (i.e.., without any major known omissions of benefit categories). That is why it is important to consider not only how new freight projects can affect vehicle operating cost and driver time cost (as experienced by carriers), but also the cost impact of changes in transportation logistics and warehousing, loading dock and order processing costs, and the scheduling of production and service providers (as experienced by shippers).

The process of translating transportation system impacts into economic impacts involves three elements that can be addressed using transportation system network models together with geographic information about traffic analysis zones (or equivalent):

- Translating time, reliability and cost impacts (by mode and trip purpose) into effects on productivity and competitiveness of affected sectors of the economy;
- Translating access impacts (which are based on improved travel speed) into effects on feasible freight delivery markets and feasible service to/from intermodal and international port facilities; and

- Translating commodity cost and access changes into industry competitiveness and market impacts at regional, national, and international levels.

After determining the effects of transportation investments on availability and cost changes for carriers and the proportion of cost changes that are passed on to shippers in the form of price reductions, first-order impacts can be estimated using economic models.

**Traditional Approach.** The traditional approach for measuring economic benefits of transportation improvements is built on models originally designed for passenger travel demand analysis. This approach focuses on estimating the value of cost reductions for vehicles and their operators, which in the freight context means the operating impacts as experienced by freight carriers. Using this approach, analysts first determine the proportion of cost reductions that are experienced by freight carriers and assumed to be passed on to shippers. In a regional or national economic model, the portion of cost savings passed on to shippers can be input to an economic model as a reduction in the "cost of doing business" for carriers and the industries with in-house transportation fleets. The model then estimates: 1) the cost savings benefit to industries that use goods and services from the carriers and other industries by way of expanded market share and business production; and 2) competitive benefits for carriers relative to other regions that lead to direct employment and output impacts for carriers and the indirect employment and output impacts at their suppliers.

**Methods to Add in Logistics Costs.** The problem with the traditional approach is that it neglects logistics-related economies of operation for shipping firms (freight system users), which can underestimate total benefits by as much as 10 to 40 percent (FWHA, 2004).[9] To compensate for this, analysts have two options. The first option is to adjust benefits calculations to include these second-order effects (which can add roughly 15 percent to total benefits) and even third-order effects, if desired (which can add an additional 0 to 10 percent in benefits, depending on the size of the transportation cost reduction). Although this approach would yield only a rough estimate of total user benefits and would yield little information on user impacts by industry, it has the merit of being less data-intensive than methods that rely on surveys of shippers and/or additional analyses of likely second- and third-order effects.

The second option is to estimate directly the impacts of transportation improvements on shippers and receivers using survey methods or apportioning benefits based on assumptions about which freight-using industries are likely to benefit most from a reduction in carrier prices. Two survey approaches are possible. For the first approach, industry users would be surveyed about the likely cost changes associated with investments. For the second approach, industries would be surveyed about transportation, modal dependence, and transportation substitution possibilities, with the results used to estimate the relative benefits likely to accrue to each industry. The

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[9] *Freight Transportation: Improvements and the Economy*, U.S. Department of Transportation, FHWA, Washington, D.C.; June 2004.

relative measures could then be used to apportion total expected user benefits to individual industries. These savings would then be modeled as reductions in cost of doing business for shippers and receivers as described above.

In lieu of survey approaches, analysts can estimate user benefits for specific shipping industries using data from the U.S. Bureau of Economic Analysis' Transportation Satellite Accounts (TSA) data, which provide measures of spending by mode per dollar of output. These data can be used with estimates of output by industry in the project area: the product of TSA and total output vectors will yield an estimate of total spending by mode by industry, which can be used to apportion total cost savings from carriers to individual shipping industries. Estimates of savings by industry can then be entered into an economic model as a reduction in the cost of doing business for each (shipping) industry. This will yield estimates of the direct and indirect effects on employment and output for freight users and their suppliers, including those that provide transportation services. However, this approach will provide a conservative estimate of the economic impact of transportation investments because it does not address second-order benefits (i.e., the reorganization of transportation and logistics systems, triggered by the reduced cost or increased quality of one or more transportation modes).

Unfortunately, it is difficult to predict a priori the economic impacts associated with second-order benefits. The empirical work on this question requires time- and resource-intensive case studies. As such, treatment of second-order effects will depend on characteristics of the analysis being performed. In cases where resources are limited and there is no reliable information on likely modal substitutions or case studies of local reorganization effects, analysts typically have focused on an analysis of first-order economic impacts and either: 1) note that the resulting benefits estimates are conservative because they neglect second- and third-order effects; or 2) adjust results to reflect likely second- and third-order impacts by increasing benefits calculation by 15 to 25 percent, depending on the size of the likely transport cost reduction. As part of the development of this report, new research was conducted to detail the actual linkage between transportation and supply chain benefits to freight shippers and receivers. That work (led by Boston Strategies International) is summarized in Appendix A and provides new estimates of expected supply chain logistics benefits that firms can experience in addition to direct transportation cost reductions. The techniques suggested by Boston Strategies International categorize industries by generic supply chain types and the importance of different transportation performance characteristics to these generic supply chain types. Then, typical cost savings from supply chain logistics adjustments can be related to the supply chain type to estimate second- and third-order impacts of transportation system improvements.

## 6.2 Industry Reorganization Effects

To translate the range of direct impacts that can follow from freight facility and service changes, it is useful to define the ways that a major transportation project may affect carriers and shippers. These are presented in Table 6.1. Not all of these parties will necessarily be affected by any one specific project, but all must be considered at the outset to ensure that the key affected parties are recognized and that appropriate methods for economic impact analysis are selected. These effects on freight carriers and shippers provide a basis for calculations and models used to estimate the national, local, and economic sector impacts of transportation investments.

**Table 6.1 Measures of Direct Economic Impacts on Carriers and Shippers/ Receivers**

| Impacts on Freight Carriers | Impacts on Firms That Ship Freight |
|---|---|
| **Inputs**<br>• Cost and capacity of affected modes | **Input**<br>• Carrier price and utilization/output by mode |
| **Results**<br>• Demand for services by mode<br>• Revenue and Value Added by mode<br>• Percent capacity utilized by mode<br>• Average shipment time (i.e., change in recurrent delay)<br>• Reliability of shipment times (i.e., change in non-recurrent delay) | **Results**<br>• Consumption of transportation, by mode<br>• Total transportation costs<br>• Warehouse utilization<br>• Inventory held<br>• Total logistics costs<br>• Consumption of logistics services<br>• Use of other inputs (e.g., labor, capital, etc.)<br>• Total production costs |

Reducing freight costs in one or more transportation modes often lowers production costs and increases market demand for freight carriers. When these cost reductions for carriers are passed on as price reductions for shippers, these investments can also influence costs, opportunities, and behavior at the shipping firms. Recent research describes the sequence by which these direct cost reductions may be expanded using logistics and productivity adjustment factors to increase the final economic benefits. The series of processes generating these additional benefits were developed in a series of studies for FHWA, and are summarized in the box below.

**Stages of Shipper Adjustment to Freight Transportation Changes**

*The description below is drawn from* *Economic Effects of Transportation: The Freight Story, Final Report*, *by ICF Consulting and HLB Decision Economics for the Federal Highway Administration, 2002, and a related discussion in* *Freight Transportation: Improvements and the Economy*. *FHWA, Washington, D.C.; June 2004.*

Benefits to shippers can be thought of as occurring in three stages:

*In the first stage*, shippers incur changes in direct transportation costs as a result of new transportation projects. Any realized increase in transportation speed and reliability and decline in transportation costs does not affect the amounts of each type of transportation and logistics service purchased by firms (e.g., rail, truck, marine, inventory, warehousing, administration, customer interactions), but only the prices that they pay for outside transportation services or costs they incur for in-house transportation. In this stage, shippers and receivers benefit from reduced transportation costs, but do not change their production or distribution processes – they merely realize a savings on the logistics-related services they already purchase. These savings have been termed "first-order benefits" (ICF/HLB, p.A-12).

*In the second stage*, firms shift the proportions of modal inputs to take advantage of the price reduction in one or more modes. That is, an increase in service quality and decline in costs in one transportation mode can lead firms to *substitute* spending on this mode in place of other modes (e.g., more rail and less trucking). Some logistics models capture inter-modal substitutions, which can also be estimated using mode choice models. These savings are a component of what have been termed "second-order benefits" (ICF/HLB, p.A-12). Preliminary research suggests that to account for second stage (i.e., substitution) impacts, "the benefits found in current benefit-cost models should be increased by about 15 percent to account for these newly measured (i.e., shipper) effects."

*In the third stage*, firms can reorganize their entire distribution systems around the availability of better or cheaper transportation services, leading to shifts among the types of logistics-related services purchased (e.g., more reliance on trucking and less on warehousing). Case studies also show that better freight transportation services can eventually spur firms to reorganize their entire distribution process, including (but not limited to) introduction of just-in-time systems. This can occur as, for example, a firm that relies on direct shipments to customers ends up adding investment and staff in computerized tracking systems, while reducing warehouse-related labor, inventory and insurance (FHWA, 2004; pp. 6, A-9, A-10).

Although logistics models generally capture intermodal substitutions, none has been identified that explicitly models substitutions between transportation and other logistics services. Survey approaches that capture both intermodal substitution and substitution between transportation and other logistics services could potentially be designed. These savings are the second component of second-order benefits. The level of benefits associated with reorganization of distribution will vary according to the size of the transportation cost reduction but can be substantial.

Prior studies suggest that when transportation cost reductions are less than 2 percent, there is little or no measurable impact on shipper benefits, but that at transport cost reduction levels of 20 percent, reorganization effects can add an additional 9 percent in benefits (ICF/HLB, p.A-14).[10] Other potential benefits include additional adjustments in operations due to reduced need for schedule padding to allow for uncertainty in delivery times. In cases where these are important, they need to be estimated separately using available reliability models.

Related work has identified additional stages related to shipper response to improved quality or reduced cost of transportation and logistics services:

- *Firms that have reorganized their distribution systems* could (simultaneously or subsequently) also reorganize their production systems. For example, firms that develop just-in-time distribution systems could use this as an entrée to introduce just-in-time production systems. Case studies suggest that savings from introduction of JIT manufacturing methods can create large savings on the assembly line.[11] However, it is very difficult to predict whether and which firms will reorganize their production systems in advance of transportation investments. To do so would require analysts or firms themselves to be able to predict the types of broad reorganization that could be undertaken years down the road; and to predict how competitors and other related actors (e.g., carriers, suppliers, and customers) would respond. For these reasons, these impacts are usually not considered in economic impact studies for proposed transportation investment projects.
- Reorganization of distribution and/or production systems can *create new capabilities that allow firms to enter new product lines*. For reasons similar to those stated above, these impacts are also generally too difficult to model.
- Firms with improved access to markets (because of better transportation systems) might *enter new geographic markets* and as a result, face demand or realize opportunities to enter new product lines. There are models ("attraction models") that estimate the effects of market access on employment and output in local areas. There are no models that explicitly link access and entrance into new product markets.

## 6.3 Establishing National and Local Distinctions

The transportation and economic effects mentioned above all relate directly to efficiency, productivity, and national economic gains. In addition to these national gains, transportation investments also lead to enhanced regional competitiveness and can affect a region's share of economic growth. In particular, some projects can reasonably be expected to have an effect on business attraction and retention. This

[10] *Economic Effects of Transportation: The Freight Story, Final Report*, by ICF Consulting and HLB Decision Economics for the FHWA, 2002.
[11] *Economic Implications of Road Congestion,* Weisbrod, G., D. Vary, and G. Treyz. 2001, NCHRP Report 463, National Academy Press.

could have a mostly off-setting transfer of activity impact at the national level, but be a benefit for local economies. While not as relevant for Federal decision-makers, local/regional economic impacts can be and are often used as partial justification for state or local funding of transportation projects.

For example, the proposed Cross Harbor freight tunnel in New York City also includes a new intermodal freight terminal in Queens that could lead to enhanced warehousing and distribution activity east of the Hudson River. This gain in activity represents a benefit for New York City regions, but could shift future economic growth in this industry from other areas (New Jersey, Pennsylvania, etc.). The key point is that traditional job estimates related to transportation projects are typically estimated at the local, state, or regional level without consideration for national macroeconomic implications. This framework is intended to focus on economic efficiency gains, but recognizes the importance of other local/regional effects, especially as it relates to justifying projects and funding from the local perspective.

Another aspect of local/regional economic benefits relates to market share for trade activity. For example, improvements in operations and connectivity at Gulf of Mexico ports in Texas could increase their share of trade activity with Latin America and the Caribbean but at the same time, reduce the share of activity in Louisiana, Mississippi, Alabama, and Florida. Such hypothetical improvements in Texas would likely have both a national efficiency benefit and a local economic competitiveness benefit.

**Use of Multiple (National and Local/Regional) Perspectives.** Among the many metrics that can be used to portray local/regional and national economic benefits, the relative importance of each of these measures will depend on the nature of the investment, its funding sources, and the objectives of the project. As depicted in the case studies to follow (Chapter 8), most large projects do have impacts across multiple jurisdictions. For example, potential Gerald Desmond Bridge improvements at Port of Long Beach are expected to produce a combination of local, regional, and national benefits, including reduced shipping and receiving costs for exporters and importers across the United States. Again, the emphasis for Federal funding decisions is on national-level impacts (benefits and costs), but there are also reasons to consider local/regional impacts for state and local funding considerations.

**National Economic Impacts.** The primary national economic impact of large-scale freight projects comes in two forms: 1) the direct transportation cost savings and productivity effects experienced by industries; and 2) the broader economic and industry effects on business output and value-added due to cost and productivity benefits. The cost and productivity benefits can be measured through first and second order effects that allow businesses to experience reductions in the cost of doing business and also produce more goods with an equal or smaller number of inputs. The broader business output and value-added[12] effects can be estimated using macro-

[12] Value-added effects by industry are consistent with the concept of gross domestic product (GDP) and is the most commonly used metric to capture the production of the U.S. economy.

economic models, translating direct effects into business productivity and international trade effects.

Competitive and business attraction benefits that accrue to the local economy will to some extent be offset by losses elsewhere in the nation. That is, when a local economy benefits from higher sales brought on by lower production costs associated with transportation projects, some of these sales will displace sales from now less-competitive locations in the U.S. Similarly, some business attraction gains spurred by improved market access will represent losses for areas that lose businesses or that would have otherwise attracted these businesses. The national economic metrics listed later in Table 6.2 represent/provide measures of the net effect of investments on national output and employment by netting out economic benefits in one area that are offset by losses in another area.

Consequently, the relationship between local/regional and national economic impacts (i.e., whether national is greater or less than local and by how much) will be shaped by a number of factors. Primarily, this relationship is determined by the magnitude of transportation cost savings for the broader economy (determined by O-D patterns) compared to any local/regional business attraction/retention effects.

This also includes the degree to which the transportation project increases the competitiveness of U.S. transportation and non-transportation firms relative to their competitors in North America and elsewhere in the world. For example, projects that improve access to U.S. coastal ports that compete with Canadian and Mexican ports will improve the competitive position of U.S. ports and the transportation firms that serve them. Projects that reduce shipping and exporting costs will also benefit non-transportation firms, especially those U.S. firms that compete in export markets. In these cases, much of the benefit to any one local economy could come at the expense of firms located outside the U.S. and thus generate a greater net national benefit than projects that benefit firms that compete primarily in regional or national markets.

The importance of sales in non-U.S. markets (i.e., exports) to the net national economic impact means that those projects that directly or indirectly affect time or cost of utilizing marine ports, airports, or (e.g., U.S.-Canada) border crossing points are likely to generate significant benefits to firms outside the "local" economy (i.e., the economic area in which the transportation project is implemented). This is because airport, marine port, and border crossing projects can all affect the cost of exporting and importing and thus will affect a broader set of firms than a project that influences only intra-area freight movements. Thus, characteristics of a transportation project will influence the relative impacts on local, regional, and national economies.

Characteristics of the local economy will also affect the impact on national economic output and employment. Many key export industries are concentrated in one or a handful of local economies. For example, in 2003, Michigan (motor vehicles) and Washington State (aircraft) each accounted for about 15 percent of all U.S. transportation equipment exports, while California accounted for about 25 percent of the U.S.' $150 billion in computers and electronics products exports.[13] Moreover, each state's export record is strongly associated with a particular metropolitan area: Detroit for motor vehicles, Seattle for aircraft, and Silicon Valley for computers and electronics. In these cases, "local" transportation projects in the vicinity of export clusters could have the potential to generate significant national benefits. Depending on characteristics of the local economy, then, projects that are primarily local in scope can lead to a significant increase in exports and thus national economic impacts.[14]

Finally, it is important to note that distributional effects on local and regional business location can lead to further economic benefits at a national scale insofar as they make better use of existing resources. For instance, if the project facilitates better use of currently available but under-utilized labor and/or capital resources, then that could represent an additional benefit in a benefit/cost calculation. On the other hand, if the project will require additional off-site infrastructure investment in order for the region to accommodate the additional population and employment growth, then those impacts should be recognized as either additional costs or a reduction in net benefit (depending on who is paying).

**Local/Regional Economic Impacts.** The biggest difference between national impacts and local/regional economic impacts is that some projects and analyses will capture a business attraction/retention effect or increase in market share that primarily benefits local/regional economies but is largely offset elsewhere in the nation such that the total U.S. benefit from those effects is near zero.

Local/regional economic impacts of transportation projects will depend on the types of improvements associated with the project. There are three general types of project effects that influence local economic activity. The first is the reduction in business costs (i.e., transportation, logistics, and production costs) from reduced travel times and costs, which improve the efficiency and competitiveness for existing users of the transportation system. The second is improved access to labor, supply, and output markets, improvements that increase the business attraction potential in the area. The third is amenity benefits in the form of things like reduced travel time and costs for non-business travel, reduction in emissions, and safety improvements.

The effects on the broader regional economy outside of the immediate local area can be positive or negative. In general, growth in a local economy will stimulate supplier activity in adjacent areas of/in the regional economy. Thus, transportation projects that improve the competitive position of the local economy should have some positive indirect impacts on the regional economy. In addition, as in the Port of Vancouver case study, projects that reduce the costs of exporting by improving time and costs associated with using local ports, will improve the prospects of exporting firms in the adjacent regional economy. The economic impact on the regional economy outside the local economy could be positive. At the same time, increases in the

[13] Calculated from the U.S. International Trade Administration data.

[14] Export growth from transportation projects in one area could, of course, offset exports from another site in the U.S. However, the offset ratio for local growth in export is likely to be far less than 1.0, while for purely local sectors (e.g., dry cleaning, restaurants), the offset ratio will be 1.0. In any case, exports are reported net of interregional offsets.

competitiveness or business attraction potential in a local economy may come partially at the expense of the larger regional economy, which could experience reduced sales or loss of potential new businesses to the now more competitive local economy. Depending on the relative weights of these factors, the economic impact in the larger regional economy can theoretically be larger or smaller than in the local economy where the transportation project is implemented. However, in most cases, the overall effect on the regional economy should be positive-that is, (positive) indirect effects in most cases will be larger than (negative) displacement effects.

## 6.4 Selection and Application of Economic Models

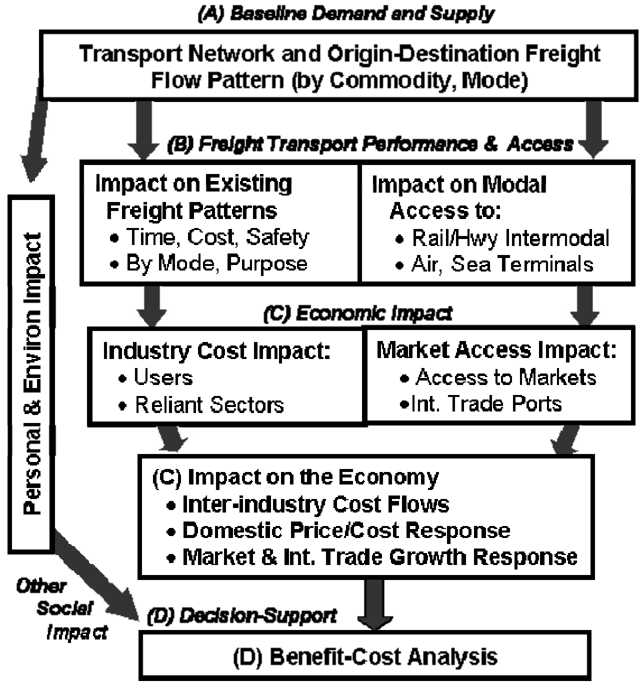
**Types of Impacts.** Large-scale freight projects can change activity levels at port or terminal facilities, and change travel times and travel costs for various modes. This can lead to resulting impacts on industry costs, markets, and international competitiveness. The national implications of such projects can start by examining implications for origin-destination travel patterns (by mode and commodity type). Additional effects on market accessibility can shift local/regional competitiveness and the potential for an area to capture more market share or retain/attract freight-related firms. Accessibility improvements that connect to major seaports, airports, or border crossings involved in international trade can also increase the competitiveness of the U.S. economy and increase the market share of international trade activity and economic growth.

Recognizing these various types of impacts, the analysis of economic benefits may require economic models with capabilities to evaluate some or all of the following six types of impacts:

1. Freight activity levels (at ports, terminals, carriers and service providers);
2. Inter-industry cost flows (whereby affected industries pass on costs to others);
3. Market access (service area expansion/contraction and economies of scale);
4. Business attraction and expansion (response to cost and access changes);
5. Domestic industry reorganization of distribution and production chains; and
6. Change in international trade.

Figure 6.1 illustrates the relationship between the various elements of economic impact, as a response to either a change in costs for existing travel patterns or a change in market access resulting from a proposed project.

**Figure 6.1 Framework for Translating Transportation Impacts Into Economic Benefits**




*See the Chapter 10 Toolbox for an overview on available economic simulation models.*

**Economic Model Options.** Depending on the situation, different types of models can be applied. The discussion which follows examines the ability of various types of models to cover the subjects of the boxes in that flowchart.

At the outset, it is important to note that there are many options for regional, national, and international trade models, including both static and dynamic forms of models. The availability of various forms of models is discussed in the Chapter 10 Toolbox. However, for purposes of this guide, it is most useful to distinguish three types of economic impact modeling.

The first level is an **input-output (I-O) model**. This is an accounting framework that can show the inter-industry sales and purchase flows for a given study area. A single region I-O model, such as RIMS-II or IMPLAN, provides multipliers that indicate how an increase or decrease in the activity of any given industry or transportation activity (such as railroads, trucking, aviation or marine transportation) will affect jobs, income and business sales for all other industries in the region. A multi-regional I-O model, as can be provided by IMPLAN and REDYN-IO, also show impacts on the economic growth and flow of commodities among regions. While these systems are sufficient for showing the economic impacts of a shift in size of freight transportation-related activities (such as investment in port expansion), they alone cannot show the impact of changes in freight costs or market access.

A variant of this second level of economic model adds **"market access" factors** to predict how economic growth can also change with shifts in speeds and connectivity that affect delivery areas and modal terminal access (as well as modal costs). The Local Economic Assessment Package (LEAP) has been used to forecast market and terminal access impacts in this way, along with I-O forecast and cost response impacts, within the context of a larger system called TREDIS (Transportation Economic Development Impact System). In general, this modeling approach is applicable for showing the regional economic impacts of shifts in multimodal terminal access and multimodal freight costs. However, it assumes that there are no further regional impacts on wage rates, cost of living, housing values, taxes and migration patterns – which can increase or decrease the overall economic impact.

The third level of economic model is a **dynamic economic simulation model**. This class of economic model provides dynamic forecasts of how regional and national economies change over time as transportation cost changes trigger a sequence of impacts. These regional economy impacts typically include: 1) changes in inter-industry cost flows; 2) shifts in supply and demand for various goods and services; 3) changes in wage rates, housing costs, and business production costs; and 4) changes in relative competitiveness, leading to in- and out-migration of households, capital investment, and business growth. In effect, this approach combines the above cited models with additional price change and migration "feedback" responses that involve some variant of "computable general equilibrium" (CGE) assumptions. REMI Policy Insight[15], REDYN (Regional Dynamics) Model,[16] and the Global Insight model are most well known in the U.S. In some areas, the Inforum, REAL, and FAIR models are also used.

In the context of this guide, a dynamic economic simulation model system can be useful to show how a reduction in freight transportation costs (for one or more modes) can reduce the relative cost of doing business in an area, which then improves the competitive position of the area because of its increase in productivity (as costs drop, the ratio of output per dollar of cost increases). That in turn leads to an increase in the relative industry growth in the area, raising demand for labor and hence wages rates, which then increases income levels and attracts more workers to move in. Due to its added cost and complexity, this form of dynamic model is most valuable for evaluating large scale projects, which involve major transportation spending, cost shifts and price changes.

**Addressing Known Problems with Economic Simulation Models.** Nearly all of the applications of economic simulation models for major transportation project

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[15] Note: All applications of the REMI model for major transportation projects have used REMI Policy Insight as part of a broader analysis framework to analyze freight cost impacts and calculate implications for industry costs (as inputs to the model). There is also a version called TranSight, which provides a limited set of transportation inputs (VMT, VHT, and accident rates for highway and bus modes), making it generally useful for straightforward urban congestion scenarios. By itself, it lacks the ability to fully distinguish freight from passenger mode impacts, to account for impacts on different commodities, or to adjust for time of day, seasonality, or reliability factors.

[16] Use of the REDYN model for transportation impact analysis is conducted through the TREDIS-REDYN system.

evaluations have required that the models be accompanied by an exogenous analysis to handle impacts that they cannot internally address. These other impacts fall into three categories.

1. First, there are impacts that are beyond price and cost effects, such as transportation *service quality and access effects*. One example is when an improvement in system reliability affects feasible delivery schedules, and hence feasible business operations (such as same day delivery limitations) which can be well beyond the mere impact on average transportation costs.
2. Also, *changes in connectivity* can affect economies of scale in serving business markets, as well as feasibility of serving broader national and international export markets that may depend on timely connections to airports or marine ports, or through international border facilities. Economic models based at the county level can miss some of these more detailed flows and cannot distinguish general traffic effects from accessibility changes to seaports, airports, universities, hospitals, etc. These effects require outside travel analysis at a finer level of spatial detail.
3. Most importantly, REMI and domestic CGE models usually assume a generally closed economy with very limited provision for *international trade impacts*. Yet these are exactly the types of impacts that are commonly associated with major, multimodal projects affecting access to ports and borders.

There are fixes for all of these problems. Some studies of major highway and rail facilities (in Illinois, Louisiana, Indiana, New York State, Appalachia, and California) have combined REMI Policy Insight with the Local Economic Assessment Package (LEAP) economic targeting model, which provides an explicit means to identify additional economic implications of both market access and intermodal access changes, using information about commodity flows. Other studies have combined REMI Policy Insight with a more ad hoc localized analysis of access and connectivity effects conducted on a project-specific basis (e.g., Iowa, New York City, Washington State, and Georgia). In some of these situations, logistics strategy analysis has also been used to identify implications for reorganization of distribution activity patterns.

Other studies of intermodal urban freight and multimodal road and rail options (in Chicago, Portland, Vancouver, and Edmonton) have used the TREDIS model. This is an economic analysis framework and economic model that evaluates how changes in transportation costs and accessibility relate to the operating requirements of various industries. It provides detail on multimodal interactions, and access impacts which affect industry competitiveness and growth.

There are many other approaches that can be applied if appropriate. For instance, it is possible to apply other types of CGE models as used in Europe (such as GAMS and Mirage), which do explicitly provide for international trade impacts. The HEAT tool (as used in Montana) provides an even more comprehensive integration of network, spatial (GIS) and economic models in a consistent framework, though its current form focuses only on highway modes. However, this kind of approach does include a highly detailed analysis of access and potential border trade impacts, with tracking of freight commodity flow changes. HEAT covers both cost and access impacts.

**Modeling Considerations.** In general, there are important reasons to tailor the form of economic analysis to the specific type of project situation to avoid unnecessary complexity, which require greater resources and additional assumptions to be made. For instance, a capacity constraint on freight flow to a port may be analyzed with input-output models to identify the indirectly affected industries, together with a logistics analysis to identify the costs and availability of viable alternative ports. On the other hand, scenarios which affect costs for international trade facilities may have implications for trade competitiveness which call for a regional economic growth model along with an international trade analysis. If the evaluation is focused instead on reducing costs of delay, then a cost response model may be needed; and if the effects are large enough to shift wage rates and business prices, then a general equilibrium model for regional simulation may be appropriate.

One final consideration when analyzing major transportation projects is the need to maintain consistency between the form of transportation model and the form of economic model. There can be the danger of a critical mismatch if a comparative static transportation model is combined with a fully dynamic economic model, since that would artificially preclude the transportation demand shifts that were previously listed, and thus put undue pressure on the economic model to over-forecast changes in businesses scale and location changes. Most transportation analysis modeling in the U.S. is currently conducted with a “comparative static” approach which represents conditions for the current time and for a target future year, with reassigned traffic routing based on least-cost or least-time paths. However, that approach usually does not allow for recalculation of time-of-day schedule shifts or international shifts of freight flows.

## 6.5 Final Analysis and Presentation of Results

**Multiple Perspectives.** The core of the economic modeling must be an analysis of how changes in travel related costs and access factors will affect the growth or decline of various productive activities within an economy. There can be a variety of different metrics used to measure economic impacts of transportation projects, which are listed in Table 6.2 below. While all can have some value, the measures of impact often need to be organized and aggregated in a way that allow for reporting of costs and benefits from different perspectives. Costs and benefits can be assigned by the affected parties (e.g., public, private, or government), by geographic incidence (local, regional, national) or by economic sectors affected (e.g., carriers versus shippers or transportation versus non-transportation sectors).

**Table 6.2 Measuring the Economic Impacts of Transportation Projects**

| Input | Output | Final Output |
|---|---|---|
| **National Economic Impacts** | | |
| • Reduced Transport Costs<br>• Reduced Logistics Costs<br>• Business Market Expansion | | • Exports and Imports<br>• Total U.S. output<br>• GDP (Value Added)<br>• Personal income |
| **Local/Regional Economic Impacts** | | |
| • Change in local production costs[a]<br>• or Change in final demand[b]<br>• or Change in accessibility/quality of rail, air/sea port, highway[c] | | • Total local output[a,b]<br>• Output from new business attraction[c]<br>• Local personal income[a]<br>• Local GDP (value added)[a]<br>• State and local tax revenue[a]<br>• Value of externalities (discussed elsewhere) |
| **Sector-Specific Economic Impacts** | | |
| • Change in production costs | • Employment by freight carriers (by mode)<br>• Output by freight carriers (by mode)<br>• Profits by freight carriers (by mode) | • Employment at logistics firms<br>• Output and Profits logistics firms<br>• Employment in non-transportation sectors[d]<br>• Output in non-transportation sectors[d]<br>• Profits in non-transportation sectors[d] |

[a]Denotes econometric model;
[b]Denotes multiplier analysis;
[c]Denotes business attraction model; and
[d]Denotes stratification by North American Industrial Classification System.

The appropriate perspective for assessing economic benefits and costs of any particular transportation project will depend on a number of factors, including the policy justification for the investment (e.g., congestion relief, local economic development, national efficiency) and the funding source (i.e., the mix of local/state/ Federal government and private funds requested or committed). However, for this analysis framework, with emphasis on large-scale projects and Federal funding decisions, we focus on three categories of economic impacts:

1. Estimates of national-level first-order and second-order transportation efficiency benefits (e.g., reduced costs to carriers and freight users);
2. Estimates of national-level economic growth or productivity (e.g., gross domestic product, business output, exports); and
3. Estimates of local/regional economic impacts for local and state funding decisions (e.g., employment, gross regional product, personal income).

As shown in Table 6.3, each of these three categories is represented, often by multiple potential indicators. For Item #1, direct transportation cost savings are the Reduced Costs in the National Economic Impacts section (and also the change in production costs in Sector-specific Economic Impacts). Item #2 is represented by the multiple final outputs within the National Economic Impacts section, and Item #3 is covered by the final outputs of Local/Regional Economic Impacts.

**Table 6.3 Example of Macroeconomic Impact Measurement by Category of Affected Party**

| | National | | Local/Region | |
|---|---|---|---|---|
| | Value Added | Wages | Value Added | Wages |
| Direct Effect (Shipper) | $ xxx | $ xxx | $ xxx | $ xxx |
| Indirect Effect (Suppliers) | $ xxx | $ xxx | $ xxx | $ xxx |
| Induced Effect (Income Re-spending) | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |
| Business Income | $ xxx | $ xxx | $ xxx | $ xxx |
| Local Use | $ xxx | $ xxx | $ xxx | $ xxx |
| Exports | $ xxx | $ xxx | $ xxx | $ xxx |
| Imports | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |

**Detailed Modeling.** The detailed modeling is to be carried out using the analysis methods discussed in Sections 6.2 to 6.4, and the tools further discussed in the Chapter 10 Toolbox. The end result will then be measures of impact on the economy at local/state and national levels, as laid out in Table 6.4. This accounting of results has several key features:

- *Income Measures.* It shows measures of benefit in terms of net income generation. This is shown both in terms of total GDP or value added (which includes labor income and net corporate earnings) and it also includes a separate measure of just the labor income generated.
- *Spatial Area.* It shows measures of the location of benefit as measured from both national and local/region/state perspectives.
- *Flow of Benefits.* It distinguishes these benefits into a) results of the direct cost, access and growth capacity benefits to shippers, b) results from reorganization of the economy due to price and demand effects on business suppliers and customers, and c) results from additional wages generating growth in consumer sectors.
- *Form of Business Growth.* It distinguishes portions of the economic expansion generated because of changes in imports, exports and domestic market growth facilitated by the investment in freight transportation facilities.

A further breakdown of these economic impacts by industry group is also generated as a standard output of most economic models. So the same form of local and national impact measurement can be shown by sector, as illustrated in Table 6.5. The results from these two tables will provide data needed for the final step of decision analysis (which is described in the next chapter).

**Table 6.5 Example of Macroeconomic Impact Measurement by Industry**

| | National | | Local/Region | |
|---|---|---|---|---|
| **Industry/Commodity Shipped** | **Value Added** | **Wages** | **Value Added** | **Wages** |
| Oil & Gas Extraction | $ xxx | $ xxx | $ xxx | $ xxx |
| Mining & Support Activities | $ xxx | $ xxx | $ xxx | $ xxx |
| Utilities | $ xxx | $ xxx | $ xxx | $ xxx |
| Construction | $ xxx | $ xxx | $ xxx | $ xxx |
| Food Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Beverage & Tobacco Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Textiles | $ xxx | $ xxx | $ xxx | $ xxx |
| Apparel Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Leather & Allied Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Wood Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Paper Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Printing & Related Support Activities | $ xxx | $ xxx | $ xxx | $ xxx |
| Petroleum & Coal Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Chemical Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Plastics & Rubber Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Nonmetallic Mineral Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Primary Metal Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Fabricated Metal Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Machinery Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Computer & Electronic Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Electric Equipment, Appliances, etc. | $ xxx | $ xxx | $ xxx | $ xxx |
| Transportation Equipment | $ xxx | $ xxx | $ xxx | $ xxx |
| Furniture & Related Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Miscellaneous Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Wholesale Trade | $ xxx | $ xxx | $ xxx | $ xxx |
| Retail Trade | $ xxx | $ xxx | $ xxx | $ xxx |
| Transportation | $ xxx | $ xxx | $ xxx | $ xxx |
| Mail, package delivery & warehousing | $ xxx | $ xxx | $ xxx | $ xxx |
| Movie, Broadcasting, Sound Recording | $ xxx | $ xxx | $ xxx | $ xxx |
| Internet & Data Processing Services | $ xxx | $ xxx | $ xxx | $ xxx |

**Table 6.5 Example of Macroeconomic Impact Measurement by Industry (continued)**

| Industry/Commodity Shipped | National | | Local/Region | |
|---|---|---|---|---|
| | Value Added | Wages | Value Added | Wages |
| Monetary, Financial, & Credit Activity | $ xxx | $ xxx | $ xxx | $ xxx |
| Insurance | $ xxx | $ xxx | $ xxx | $ xxx |
| Real Estate | $ xxx | $ xxx | $ xxx | $ xxx |
| Rental & Leasing Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Professional, Scientific, Technical Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Educational Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Health Care & Social Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Amusement & Recreation | $ xxx | $ xxx | $ xxx | $ xxx |
| Accommodations, Eating & Drinking | $ xxx | $ xxx | $ xxx | $ xxx |
| Repair, Maintenance | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |

# 7 STEP 5: SELECT AND APPLY DECISION METHODS

Once benefits have been identified, and where possible quantified, it is necessary to convert this information into investment decisions. While there is an element of subjectivity in this process, it is best to establish a defensible, repeatable decision procedure where possible.

## 7.1 Alternative Views of Benefits

Depending on the project and the economic analysis tools employed, there are a number of different economic impact measures that can also be applied to the decision-making process. Since projects vary in size and cost, it's important to find measures that allow for fair comparisons when considering funding decisions for large-scale freight projects. For example, the measure could be related to the cost, as reflected in an impact of dollars of income generated in the economy per million dollars of cost. As mentioned in Step 2, we expect all projects will produce at least 1) a dollar-based estimate of transportation cost savings (likely a combination of travel time and actual costs); and often also 2) a measure of national economic productivity, perhaps in terms of business output, increased trade, or gross domestic product (GDP). This second measure would capture second and third order economic effects not captured by the direct transportation cost savings. Therefore, decision metrics could include:

- Business-related transportation cost savings per $1 million of project costs;
- International trade per $1 million of projects; or
- Increased GDP per $1 million of projects.

For evaluating large-scale freight projects, and determining potential Federal funding contributions, it is essential to consider both economic benefits and costs. Typically, government agencies take a broad view of benefits to include the full range of public benefits. This economic evaluation framework is limited in a benefit-cost sense since it does not capture the full range of effects (e.g., environmental factors), many of which are very difficult to quantify. The concepts most relevant to this framework include various measures of economic impact. A measure such as economic cost savings per million of project costs (or similar) might be the most helpful metric to use when evaluating projects and comparing economic effects with other transportation, social, and environmental factors.

## 7.2 Benefit-Cost Calculation and Presentation

Benefit-cost analysis[17] compares the present value of the benefits of an investment against the present value of the costs of a proposed investment. There are two fundamental results from performing a benefit-cost analysis: 1) net present value (NPV); and 2) benefit-cost ratio. The "Present Worth" of a project is commonly referred to as its NPV. The NPV of the project is obtained by summing the discounted benefits and costs for each year using a discount rate. Discounting is conducted to compare benefits and costs that typically occur over different timeframes for a single project. Generally, projects that attain an NPV > 0 are worth investing in – the benefits over time outweigh the costs over the life of the project.

The benefit-cost ratio is estimated simply by dividing the present value of benefits by the present value of costs. A benefit-cost ratio above 1.0 is consistent with a project that has a NPV > 0. A benefit-cost ratio of 1.0 represents the lowest value that should be considered for a transportation investment if no other non-monetary factors are to be considered, and if there is no uncertainty in the analysis. These conditions never exist in reality.

Benefit-cost analysis (BCA) can be extended as a methodology to rank different projects, all of which may have NPV of greater than zero and, therefore, are theoretically worthwhile. In a capital-constrained situation, it is not possible to invest in every project with a positive NPV, and therefore a way to prioritize is required. The benefit-cost ratio is a measure of return on investment – "bang for the buck."

When the objective of a study is a benefit-cost comparison for a single project, it is important to estimate the full range of benefits, including second- and third-stage benefits, associated with the project. When the objective of a study is to compare costs and benefits across existing or potential projects, it is more important to use consistent sets of benefits measures and methodologies, which can be some combination of first-, second, and third-stage benefits.

There are guidebooks that have been developed by modal agencies in the U.S. (FRA, FAA, and FHWA) that provide guidance on the application of benefit cost analysis for rail, highway, and aviation investments. There are also several international guides and a new web-based guide (hosted by California Department of Transportation (Caltrans)) that spans all modes. These guides also discuss available benefit-cost tools. Discussion of further tools for benefit cost analysis and available guides are contained in the Chapter 10 Toolbox.

[17] For further description, see "Economic Analysis Primer," U.S. Department of Transportation, Federal Highway Administration, Office of Asset Management, August 2003.

# 7.3 Incidence and Equity of Benefits and Costs

For evaluating projects that span multiple government jurisdictions as well as public and private interests, there is an important need to consider how the costs and benefits are distributed among various categories of stakeholders. There are two approaches that can help to address this need.

*The analysis framework laid out in this guide is designed to facilitate multimodal benefit-cost analysis.*

**Multimodal Benefit-Cost Analysis** is a form of standard benefit cost analysis in which the benefits and the costs are accounted separately for each mode. That approach can allow for distinction between passenger and freight travel benefits when transportation facilities are shared by both groups. It can also assist in distinguishing benefits associated with privately owned modal facilities (e.g., most rail facilities) from those associated with publicly owned modal facilities (e.g., most highway facilities). Systems such as *TransDec (Transportation Decision Analysis Software)* and *TREDIS (Transportation Economic Development Impact System)* accomplish these goals, as described in the Chapter 10 Toolbox. Both systems are also noteworthy for their ability to also cover accessibility and connectivity benefits and economic growth impacts as well as implications of cost savings for existing freight flow patterns.

The analysis framework laid out in this guide is designed to facilitate multimodal benefit-cost analysis of this type, as illustrated in Table 7.1.

**Table 7.1 Example of Multimodal Benefit Accounting**

Net Present Value of Benefit Stream

| | by mode | Pass Car/ Lt.Truck | Truck Freight | Rail Freight | Bus/Rail Transit | Air Transport | Water Transport |
|---|---|---|---|---|---|---|---|
| (A) | Cost of Transport | x | x | x | x | x | x |
| (B) | Cost of Time Delay | x | x | x | x | x | x |
| (C) | Cost of Accidents | x | x | x | x | x | x |
| (D) | User Logistics/Prod Cost | x | x | x | x | x | x |
| (E) | Personal Time | x | x | x | x | x | x |
| (F) | Social & Environmental | x | x | x | x | x | x |
| (G) | Net Inward Investment | x | x | x | x | x | x |
| -- | Capital Cost of Project | x | x | x | x | x | x |
| -- | Operating Cost of Project | x | x | x | x | x | x |

| Benefit Concept | Definition | Net Benefit (Benefit-Cost) | Ratio (Benefit-Cost) |
|---|---|---|---|
| Transport System Efficiency | = A+B+C | x | x |
| Transport User Cost Savings Benefit | = A+B+C+D | x | x |
| Total User Benefit | = A+B+C+D+E | x | x |
| Total Social Benefit | = A+B+C+D+E+F | x | x |
| Total Regional Income Benefit | = A+B+C+D+F+G | x | x |

**Multiple Criteria Appraisal (MCA)** is most popular in Europe as a more comprehensive alternative to the use of BCA. It provides a means of considering the wider issues of qualitative and quantitative benefits and costs in a unified framework based on rating criteria and weighting systems. MCA relies on interpretation from analysts/stakeholders to value a wide range of expected benefits and costs. The additional issues can include considerations of progress towards policy goals relating to access, economic, environmental, international trade and distributional impacts. Examples of MCA systems are described in the Chapter 10 Toolbox.

# 8 EXAMPLES OF APPLYING THE GENERAL APPROACH

## 8.1 Building Examples of Techniques and Use of the Economic Impact Analysis Framework from Current Practice

This chapter of the guidebook provides a practical example of how the five step economic impact analysis framework can be applied to a real-world project using a wide range of transportation and economic impact analysis tools. In order to develop this example, we have started with an actual example of an economic impact analysis of a major freight rail program in Baltimore, Maryland. The original economic impact analysis conducted for this project is fairly typical of the better economic impact studies of freight projects and it incorporates a fairly extensive evaluation of cross-modal economic impacts and provides much useful data on transportation performance benefits of the proposed project. In order to illustrate the usefulness of the five-step framework, we have taken this original economic impact analysis, re-cast it in the five-step framework, and illustrate how the range of the analysis can be extended to more comprehensively address the economic benefits and impacts of the proposed investments. This should provide users of this guidebook with a clearer picture of how they might apply the economic impact analysis framework to their own investment analyses.

The Baltimore rail project example is only able to illustrate the use of the framework for analysis of one type of freight project (rail corridor improvements) and it uses a particular set of impact analysis and modeling tools appropriate to the budget and concerns of the Maryland Department of Transportation (MDOT) at the time the analysis was conducted. In order to illustrate impact evaluation tools that cover a wider range of project types and tools that can be used with varying budgets and levels of effort, we have included a series of mini-case studies in the Appendix B of this guidebook. While none of these case studies illustrate applications of the five-step framework in its entirety, they do provide examples of how different tools and techniques can be used to conduct specific parts of the analysis covering a wide range of conditions. The mini-case studies have been "mapped" to the five steps in the process so that it will be easier for the reader to see how specific tools and techniques could be applied to the framework developed in this guidebook. There is a review of the case studies included at the end of the Appendix B that also points out the degree to which the case studies do and do not incorporate specific features of the economic impact analysis framework described in this guidebook.

## 8.2 Case Study: Baltimore Freight Rail Bypass

In order to illustrate the application of the analysis approach developed in this guidebook, a case study of the Baltimore Freight Rail Bypass project is first presented describing how the analysis was conducted by the MDOT and its consultant. It is useful to take this original analysis and present it in terms of the five steps in the guidebook approach for illustrative purposes (although the analysis was not originally conducted with this framework in mind). This is followed by a re-working of the case study analysis to apply additional aspects of the five step framework process and to show how a more comprehensive economic impact analysis conducted in accordance with this approach would yield a different result.

### Step 1 – Classify the Type of Project

The Mid-Atlantic Rail Operations Study (MAROps) report released by the I-95 Corridor Coalition in 2002 noted that significant choke points existed within the region, and that these were hurting current rail performance and limiting future rail growth.[18] The report specifically stated that the "CSX Howard Street Tunnel [in Baltimore, Maryland]…[is an] antiquated, single track tunnel with limited vertical clearances that preclude double-stack trains." When the tunnel was hit by a fire in July 2001, the dependence of the United States' east coast corridor rail traffic on key stretches of track was effectively demonstrated. The 60-car CSX fire took the emergency services almost a week to bring under control, and severely impacted east coast rail operations for some time afterwards. Other tunnels in Baltimore include the Union Tunnels (built in the 1920s) and the B&P Tunnel (built in the 1870s), both of which are in need of rehabilitation due to deterioration and lack of vertical clearance.

A study commissioned by the MDOT was entitled, *The Economic Benefits Estimates for the Baltimore Rail Framework Plan*. The focus of the Baltimore Rail Framework Plan study was the congested railroads located in and around Baltimore. The railtrack is shared by freight and passenger rail, with ownership resting in the hands of several companies. Following a series of train delays and reports indicating the need for track improvements, the decision was made to study the economic benefits of the Rail Framework Plan that had been designed to reduce the pressure on the congested tracks. The plan suggested improvements that included new tunnels beneath the city of Baltimore and alternate alignments that would bypass the city.

The improved alignments represent link level capacity enhancements by upgrading track and tunnel conditions. The project might also be considered a link level operational improvement. To the extent that these improvements to rail service

[18] *Mid-Atlantic Rail Operations Study Summary Report*, I-95 Corridor Coalition, April 2002.

characteristics attract more rail users, the project might also have modal diversion impacts.

## Step 2 – Define the Relevant Evaluation Issues

The purpose of the economic analysis of the Baltimore Rail Framework Plan for MDOT was to calculate the estimated benefits to freight rail operators, intercity rail passengers, and the public. The study quantified the benefits of the proposed new alignment from three perspectives:

- The benefits for existing freight rail users from reduced travel times and the removal of bottlenecks (and other potential cost of service benefits passed on by the railroads to their customers);
- The shipper cost savings that result from the maintenance of freight rail mode share (i.e., reducing future truck growth); and
- The benefits to the highway system from reduced future truck VMT in the form of reduced air pollution, noise, collisions, and highway/bridge maintenance costs.

The allocation of benefits were modeled for Maryland only, and covered the marginal cost reduction per train, the cost savings to the shipper, environmental and safety benefits, and reduction in highway maintenance costs. Reduced highway congestion and travel times for the remaining autos and trucks on the highway system were not estimated in this study.

## Step 3 – Select and Apply the Analysis Tools to Estimate Transportation Impacts

In order to calculate the benefits anticipated for the existing freight rail operators, the report utilized:

- The FHWA's Freight Analysis Framework's (FAF) projections to estimate current and future rail freight flows that terminate, originate, or move within Maryland; and
- The Maryland Rail Study operational estimates of delay and throughput time savings derived from new freight rail alignments used by existing freight trains and consequently bypassing the current B&P and Howard Street Tunnels.

Since the FAF database presents freight flow in total tons, the forecast shipments were converted to 20-car trains with car payloads estimated at 56 tons each. The crew cost per hour was based on an estimate of the cost of a train comprised of one locomotive pulling 100 FEUs over a 16-hour period. The new alignment was estimated to save 6 hours over current conditions.

The savings that result from the maintenance of freight rail mode share were also calculated using the FAF database. The existing FAF forecast predicts a growth in freight rail volumes, with an even higher growth rate for trucks. The analysis assumed that the new alignment would make rail a more attractive mode choice due to the improved efficiency and reduced costs over present conditions. As such, the existing mode share for freight rail was applied to the projected total freight shipments to estimate the increased level of rail freight (and a corresponding reduction in truck freight).

The travel time benefits for Amtrak intercity rail passengers were based on the reduction in the trip time (30 minutes) estimated from improvements to the Northeast corridor. The analysis shows that the Maryland share of origin-destination based benefits is 30 percent. Consequently, 70 percent of the benefits are allocated to non-Maryland residents traveling through the state, but benefiting from rail bottleneck improvements in Maryland. The estimate of a 30-minute travel time savings for Amtrak riders was based on assumptions rather than simulation modeling.

The impact of potential time savings for trucks and autos on those highways that experienced a decrease in traffic due to the diversion of cargo to rail was not explored.

## Step 4 – Select and Apply Analysis Tools to Estimate Economic Impacts

The six hours in time savings anticipated for the existing freight rail operators who would instead use the bypass route were used to calculate a reduction in crew costs and car lease costs. Existing freight train crew and unit costs savings were based on cost data that was obtained from the U.S. DOT, CSX, NS, and a Port Authority of New York and New Jersey publication.[19] The crew cost was valued at $175 per hour, based on the cost of a train comprised of one locomotive pulling 100 FEUs for 16 hours (equivalent to approximately 300 miles). The daily car lease costs were valued at $45 per car per day.

The increased level of rail freight and reduced level of truck freight projected due to the improved efficiency of freight rail was used to calculate a number of benefits. The resultant decrease in truck activity would have a variety of positive economic impacts, including reduced transport or shipper costs due to lower per ton costs for rail versus truck, and reduced environmental and highway maintenance cost savings due to fewer trucks and less truck VMT on the state's highways. Benefits originating from the recapture of freight from truck to rail were assumed to only occur for those trips that that originated or terminated in Maryland, but did not include intrastate trips since these were deemed too short for recapture.

[19] *Rail Short Haul Intermodal Corridor Case Studies*, Foundations for Intermodal Research and Education, March 2003.

Pecuniary values were assigned to the truck VMT reductions consistent with the values used in the MAROps Interim Benefits Assessment study.[20] Cost savings were based on 4.5 cents per ton mile transportation rate for rail in 2004 (remaining flat in future years) and 8.0 cents per ton mile transportation rate in 2004 for truck (increasing to 10.0 cents per mile by 2020). This results in a 3.5-cent shipping cost savings per affected ton mile in 2004, growing to 5.5 cents in 2020. This analysis did not take into account the differences in travel time and reliability between rail and truck (which might dampen the benefits as trucks tend to have faster travel times). Instead, the analysis focused on cost per ton mile differences and assumed that current rail shippers would prefer to stay with rail in the future, and are therefore comfortable with the time and reliability of rail.

The reductions in collision costs, air pollution, and noise pollution were derived based on steady cents per truck mile rates. Highway maintenance cost savings were calculated for reductions in pavement deterioration repair, pavement improvements, and bridge costs. The value of the total economic benefits for freight diverted from truck to rail were substantially larger than those benefits projected for existing freight rail users.

The 30 minutes in travel-time savings experienced by intercity rail passengers was valued at $30.00 per hour, which was based on other reports, including the Intercounty Connector study. Amtrak ridership data were used to determine the number of trips that originated or terminated in Maryland, and were multiplied by the $15.00 value in travel-time savings. While the number of passengers who traveled through the state was extracted from the ridership data, the benefits that these passengers would receive were not calculated.

## Step 5 – Apply Relevant Decision Methods

This analysis did not include a formal benefit-cost analysis, and given the focus on statewide benefits (excluding regional and national benefits), that may be appropriate. The benefits to Maryland over the 20-year period were valued at $253 million from existing rail freight, $1,340 million from the recapture of mode share from truck to rail, and $293 million from the current intercity rail passengers. The total benefits projected to be seen by the state were estimated at $1.89 billion.

## Application of the Framework for Baltimore Freight Rail Bypass

This section of the report details the application of the analytical framework set forth in this document to measure the economic benefits of freight transportation investments. As discussed, preliminary work has been conducted by Maryland DOT and their consultant (PB Consult) to estimate the future benefits of this project. The analytical framework uses results from the technical memorandums generated by PB

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[20] Mid-Atlantic Rail Operations Study *Interim Benefits Assessment*, I-95 Corridor Coalition, February 2004.

Consult (dated March 31, 2005 and August 19, 2005), and by applying the analytical framework, it expands on this initial work by:

- Capturing national-level benefits in addition to the benefits to Maryland's shippers and residents;
- Including highway system benefits due to a reduction of truck travel (because of improved freight rail service);
- Expanding the analysis from a purely transportation user perspective to an industry-based perspective that recognizes the benefits to businesses of more efficient goods movement; and
- Including a benefit-cost analysis and conducting sensitivity analysis.

Consequently, this application of the framework quantified the benefits of the proposed new alignment from five perspectives:

1. *Existing freight rail.* The benefits for existing freight rail operators from reduced travel times and the removal of bottlenecks (and other potential cost of service benefits passed on by the railroads to their customers).
2. *Shipper cost savings.* The shipper cost savings that result from maintaining freight rail mode share (i.e., reducing future truck growth).
3. *Highway benefits.* The benefits to the highway system from reduced future truck VMT;
4. *Passenger rail time savings.* The benefits for existing Amtrak users who would experience an improvement in travel time through the region.
5. *Supply chain benefits.* The supply chain benefits that shippers would enjoy due to the infrastructure improvements. These include access to lower-cost supply sources, the consolidation of facilities (due to greater market reach), and the reduction of inventory through smaller order quantities.

These adjustments to the analysis primarily affect Step 3 (by extending the analysis of shipper benefits from maintaining rail mode share to include shippers outside of Maryland; including highway user benefits for all highway users; and including travel time savings to all Amtrak users not just those in Maryland), Step 4 (by including the direct cost savings of maintaining rail mode share for rail users outside of Maryland, by calculating the direct economic benefits to all highway users based on an application of the Highway Economic Requirements System (HERS), and by incorporating potential second and higher-order supply chain benefits), and Step 5 (by incorporating a full benefit-cost analysis as part of the decision methods). These adjustments to the original economic analysis involve relatively modest changes in terms of overall level of effort applied. Had more resource been available, several other modifications to the analysis approach could have been incorporated and these might be considered by Maryland DOT if it proceeds with the project and seeks other government funding partners:

- The analysis of existing rail operator benefits could be conducted with more detailed rail simulation models taking into account the different commodity movements in the corridors and train types to get a more accurate estimate of time savings and associated costs based on the actual traffic mix (i.e., carload traffic vs. intermodal traffic and relative costs).
- The analysis of shipper benefits associated with modal diversion could be estimated using a more detailed modal diversion model
- The analysis of highway user benefits could be based on an actual travel demand model that would calculate actual travel time savings and associated benefits in terms of improved reliability of the highway system, reduced accidents, and reduced emissions (several of these benefits are included in the HERS cost factors but through more aggregate analysis techniques).
- An economic impact analysis model could be run to determine how business cost savings as calculated in the approach as presented herein would affect GRP/GDP, employment, and other macroeconomic indicators.

The adjustments to the original analysis and source for deriving these benefits are explained below.

**Existing Freight Rail Operators**

One component of the original analysis focused on the effect that the proposed investment would have on CSX and Norfolk Southern (NS) operations in the Maryland region. It was estimated that the improvements would lead to a combined travel cost savings of $22 million in 2010, growing to nearly $30 million by 2039. A brief summary of the analysis for CSX and NS is presented below. This aspect of the analysis was not adjusted in the re-work of the case study but the details of how the travel savings and cost benefits were calculated are presented here in order to provide users of the framework with a clearer picture of how the analysis was conducted.

**CSX.** The current CSX alignment through the Baltimore region runs parallel to Amtrak's Northeast Corridor (NEC) through downtown Baltimore, but it is redirected south at the Howard Street Tunnel to Camden Yards and then continues southwesterly towards Washington. A mid-harbor tunnel would provide a more direct route through the downtown area, resulting in shorter travel times for the 22 trains that would use it on a daily basis.

It was estimated that 20 of those daily trains would experience a ten-minute reduction in travel time while the remaining ones (given a difference in route) would save six hours on average. These numbers would result in an average savings of 42 minutes per train (Step 3).

PB Consult worked in collaboration with the U.S. DOT, FRA, CSX, and NS to produce an estimated cost per car-hour that would allow them to quantify the time savings into dollars. For this route, they estimated cost per car-hour of $17.00. Given the average savings of 42 minutes and the nearly 1.1 million cars projected to be moving along the route in 2010, the improvements are expected to generate approximately $10.0 million in benefits during that year. The traffic volume is expected to increase to 1.5 million cars by 2039, producing a cost reduction of $13.2 million.

**Norfolk Southern (NS).** While NS does not currently use the NEC for freight rail shipments from the South to the New York metro area, they hold trackage rights to the Corridor and could resume use of it whenever they see a favorable opportunity. If NS were able to use the mid-harbor tunnel routes, it would be necessary to build connections to and from the Corridor at either end, and grant them trackage rights over the tunnel approaches, which are owned by CSX. The mid-harbor alignment would be a more direct route on this corridor through downtown Baltimore. PB Consult estimated that this would save NS approximately 15 minutes per train based on pure running time, but considering actual operations it would be closer to two hours (based on waiting time to get an opening through the B&P Tunnel, their present route). In addition, NS sends about 10 trains per day through the Shenandoah Valley route in Pennsylvania and western Maryland. This circuitous route adds another 6 to 8 hours in travel time for these trains, but avoids the delays on the NEC.

Assuming a 120-minute time savings for NS trains and an estimated total of 486,000 cars passing along the route during one year, NS will realize a cost savings of $12.4 million due to the improvements in 2010. This figure will grow to $16.5 million by 2039 from 674,000 cars.

**Shipper Costs Savings**

The analysis for Maryland DOT assumed that freight rail would experience higher volumes of future freight rail tonnage if the project is built (essentially consistent with today's mode share applied to higher future total freight volumes). This assumption was consistent with the methodology assumed in the Mid-Atlantic Rail Operations (MAROps) "Interim Benefits Assessment" from March 2004. This results in more rail freight and less truck freight, which lowers overall shipping costs for businesses. The benefits of this scenario are derived from the cost savings associated with transporting by rail versus truck and are independent from the benefits to existing rail users who would use rail even without the improvement project.

The Maryland DOT analysis included the shipping cost benefit of maintaining the freight rail share for freight originating or terminating in Maryland, but did not include intra-Maryland trips, which were deemed too short for rail. The benefits were estimated using the per ton-mile costs presented in the MAROps study. In this report, a ton-mile by rail would cost a shipper 4.5 cents versus 8.0 cents by truck in 2004; the cost of shipping by truck was expected to increase to 9.0 cents by 2010, and 10.0 cents by 2020 due to congestion, while the cost for rail was assumed to remain constant.

In order to extend the original analysis, the FAF data were consulted to determine the number of trips using the MD rail system that were through trips. These data were analyzed to determine the amount of truck tonnage in the future FAF forecast would need to be maintained on rail in future years to preserve rail mode share. The cost savings to these shippers from using rail vs. trucking would add to the benefits previously calculated in the original MD DOT analysis for those trips with origins or destinations in MD that would be maintained on rail as a result of the rail improvements.

The average trip distance for freight rail trips in MD was obtained from the State's shipment characteristics published on the 2002 Commodity Flow Survey (CFS). The average distance for trips originating or terminating in MD is approximately 300 miles, while through trips were assumed to be traveling on average 500 miles[21]. These data could then be applied to the inter-MD and through-MD tonnage numbers calculated as described in the previous paragraph in order to estimate ton-miles that could be retained by rail in the future.

Using the numbers provided by PB Consult (regarding modal shift), along with the assumptions about ton-mile costs and trip distance, the shipper cost savings for the entire nation (all trips traveling on the rail system in MD) were estimated at $64.3 million in 2010, increasing to more than $300 million by 2039.[22] Estimating the total shipper cost savings for all trips (including trips passing through Maryland) increases the national benefit significantly as the Maryland-only shipper cost benefit in 2010 is $39.5 million (see Table 8.1).

**Table 8.1 Transportation and Economic Benefits in 2010**

| | Reworked National Analysis | Maryland-Only Analysis | Difference |
|---|---|---|---|
| Freight Rail Operators | $22,400,000 | $22,400,000 | $ - |
| Shipper Costs | $64,261,665 | $39,465,442 | $24,796,223 |
| Highway Costs | $72,691,635 | $25,725,621 | $46,966,014 |
| Amtrak | $57,303,336 | $16,137,797 | $41,165,539 |
| *Subtotal* | *$216,656,635* | *$103,728,860* | *$112,927,775* |
| Supply Chain | $61,900,522 | N/A | N/A |
| **Total** | **$278,557,157** | **$103,728,860** | **$174,828,297** |

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics.

Notes: The highway benefits for Maryland were estimated by PB Consult based on a reduction in pavement deterioration repair, pavement improvements, and bridge costs – a different approach than the national level. The Amtrak benefits for Maryland were estimated using the trip purpose split and adjusted travel time values estimated by Cambridge Systematics (resulting in slightly more conservative results).

[21] PB Consult originally used estimates of 500 miles (for trips originating and terminating in MD) and 750 miles (for through trips). Based on the CFS data, these were deemed to be somewhat aggressive, and consequently, the average distance was lowered. In an attempt to maintain the same ratio used by PB Consult between through and non-through trips, an estimate of 500 miles was used for through trips.

[22] Cambridge Systematics created linear time-series for all benefit concepts to assess benefits over time and estimate benefit-cost measures. The use of linear extrapolations is more conservative than an alternative approach of using exponential growth factors.

### Highway Travel Benefits

Highway travel benefits extend from the assumption that the improvement in the rail infrastructure will create a decrease in truck traffic throughout the highway system. This will result in a number of benefits including:

- Reduced highway maintenance costs;
- Reduced congestion for the remaining highway users; and
- Reduced accidents for the remaining highway users.

In the original analysis, PB Consult only considered the highway maintenance cost benefits.

PB Consult estimated that this project would take nearly 426,000 trucks off Maryland's roads in 2010, growing to approximately 866,000 by 2020. Out of this total, approximately 16 percent was associated with through trips (with origin and destination outside of the State), while the remaining share had either an origin or a destination in the State.

As mentioned in the previous section, freight rail trips originating or terminating in Maryland were assumed to be traveling 300 miles on average, while through trips would travel 500 miles. Using these numbers, the total truck VMT reduction for 2010 would be nearly 143 million miles, and would surpass 560 million miles by 2039. These numbers were used to estimate the reduction in travel time and costs for the cars and trucks remaining on the highway system.

A simple way to estimate the full highway user benefits of the Baltimore Rail project was developed by using results of HERS runs prepared for the MAROps study (the Baltimore project involves highway users and highway networks that are a portions of that included in the MAROps analysis and is, therefore, considered similar enough to use for this purpose). The VMT reduction numbers derived above for the Baltimore project were compared to those used in the MAROps study to obtain the travel benefits. The total VMT reduction expected as part of the Baltimore Rail project is expected to account for approximately 23 percent of all of the proposed MAROps improvements; hence it was assumed that the project would produce the same proportion of travel benefits and thus the 23 percent figure was applied to the total MAROps highway user benefits calculated with HERS. Using this approach, auto travelers (for work or pleasure) would save a combined $61.5 million in 2010 and $82.2 million in 2039, while truck travelers would experience savings of $11.2 million in 2010 and $15.0 million in 2039 as a result of the Baltimore project. This includes consideration of all highway users and all categories of highway user benefits as distinct from the way the analysis was done originally, including only the pavement and bridge maintenance benefits. In total, the benefits would amount to $72.7 million in 2010, growing to $97.2 million in 2039.

This benefit share (23 percent) is consistent with the costs associated with the project in relation to the additional MAROps projects. The original MAROps plan included two projects with significant improvements to the Howard Street and B&P Tunnels.

These improvements were comprised of additional (new) track, better clearance, and improved alignments. The two projects were expected to cost $1.26 billion, or approximately 20 percent of all proposed MAROps projects ($6.17 billion).

**Amtrak Travel Benefits**

PB Consult estimated that the infrastructure improvements from the project in question would provide Amtrak riders with a 30-minute improvement in travel time through the region. Amtrak ridership data was obtained from the PB Consult report and reveal that currently 5.2 million riders would be affected by this project (30 percent of them traveling to or from Maryland while the rest are through passengers, providing the basis for extending the analysis to include benefits to all Amtrak users that would benefit from the improvements). For purposes of this analysis, it was assumed that the average value of travel time for Northeast corridor riders is $30.00 per hour for business travelers and $15.00 per hour for the remaining riders.[23] Different trip purpose splits were assigned to all the routes, which combined for a total 46 percent[24] business travelers, or 2.4 million people per year.

Using the assumptions stated above, the 30-minute reduction in travel time would result in savings of $36.2 million for work-related trips and $21.1 million for the remaining ones, adding up to a total of $57.3 million in savings in 2010. Lacking ridership forecasts for this section of Amtrak passenger rail, it was assumed that this figure would remain constant through 2039.

**Supply Chain Benefits**

In addition to addressing the monetary benefit of transportation impacts to the users of the transportation system, the re-worked case study also examined the supply chain effects created by this freight investment. In particular, the analysis uses the results presented thus far in terms of reductions in the costs of shipping goods, and estimates an additional "second order" supply chain/logistics benefit to the industries most affected by an improvement to the rail system. The methodology for deriving these benefits was obtained from the Boston Strategies International (BSI) "Framework for Assessing the Supply Chain Benefits of Large-Scale Transportation Infrastructure Projects," which is included as Appendix A of this guidebook. The basic approach developed by BSI is to estimate a percentage increase added to direct freight system user benefits that are associated with supply chain improvements (benefits). These percentage increases vary depending on the type of supply chains that are dominant in the industries that are affected by the project. This recognizes that different supply chain types are able to take greater or lesser advantage of transportation cost saving.

[23] In the March 31, 2005 memorandum from PB Consult to Maryland DOT, they use a value of $30.00 per hour for all Amtrak NE Corridor riders. The assumption used here is more conservative and accounts for passenger travel that is not of a business nature.

[24] Fifty percent of the people traveling through Maryland were assumed to be doing so for business, 25 percent of people traveling to/from MD on the NE Corridor were assumed to be doing so for business, while 50 percent of those traveling to/from MD on the remaining lines were doing so for the same purpose. The combination of these percentages and the ridership results in 46 percent of people traveling for business.

The types of impacts included in the supply chain analysis include:

1. A possible reduction in material costs, stemming from cost-effective access to lower-cost supply sources;
2. The consolidation of plants due to extended market reach; and
3. The reduction of inventory through smaller, more frequent order quantities.

In general, shippers use lower transportation costs to source from less expensive suppliers, which increase their profit margins. They are also able to deliver at lower costs per shipment. Because of transportation improvements that reduce travel time and increase reliability, they can operate fewer plants since they can achieve greater market reach from each one, thereby reducing costs and increasing return on assets. Finally, shippers also opt for smaller shipments, which had been prohibitively expensive, and thereby decrease the needed level of inventory.

To quantify each of these impacts, the full-range of industries was divided into the six "Supply Chain Types" defined by BSI: Extraction, Continuous Flow Manufacturing, Make-to-Stock Manufacturing, Design-to-Order Manufacturing, Distribution, and Retailing. As shown in Appendix A, BSI has associated industry sectors (identified by industry classification codes) with the supply chain type that is found most predominantly in that industry. In some cases, industries are allocated among multiple supply chain types. For this portion of the study, the number of jobs in each industry sector was obtained from the Bureau of Labor Statistics for the greater Mid-Atlantic Region, consisting of Delaware, Maryland, North Carolina, New Jersey, New York, Pennsylvania, Virginia, and West Virginia. Once these were obtained, the share of jobs in each Supply Chain Type™ was calculated as shown in Table 8.2.

**Table 8.2 Share of Jobs by Supply Chain Type™**

| Shipper Type | % of Jobs |
|---|---|
| Make-to-Stock Mfg. | 29% |
| Retailing | 27% |
| Design-to-Order | 18% |
| Distribution | 15% |
| Continuous Flow Mfg. | 7% |
| Extraction | 4% |

Source: Bureau of Labor Statistics.

The next step was to extract the direct freight-related benefits from the previously analyzed total transportation impact categories. Freight-related benefits were defined as the benefits accrued by existing railroad operators, shipper costs savings, and the benefits associated with truck travel on the highways. The sum of the freight benefits for several selected years is shown in Table 8.3 below.

**Table 8.3 Freight and Supply Chain Benefits**

| | 2010 | 2015 | 2025 | 2039 |
|---|---|---|---|---|
| Freight-Related | $97,869,010 | $146,483,597 | $243,802,873 | $379,986,788 |
| Supply Chain | $61,900,522 | $92,648,440 | $154,201,265 | $240,335,327 |

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics.

These freight-related transportation benefits were then assigned to each Supply Chain Type™ using the percentages from the previous table.[25] Finally, the analysis made use of the parameters estimated by BSI to calculate potential second order industry logistics effects. For each of the three types of freight-related direct impacts, BSI estimated the Supply Chain benefits as a percent of the reduction in transportation cost, and they also provide index values for the relative amount of externally purchased materials, fixed asset intensity, and value of inventory, by each Supply Chain Type™ to better capture how these benefits will vary by industry. These values allow for the quantification of all three impacts for each Shipper Type. As shown in the table below, the sum of the supply chain benefits for 2010 is expected to be $62 million, growing to $240 million in 2039, indicating that the logistics effects can exceed 60 percent of the direct freight-related transportation benefits.

**Benefit/Cost Analysis**

To help understand the value of the Baltimore rail improvements, the project team conducted a benefit/cost analysis. As described in the analytical framework, benefit/cost (B/C) analysis is one potential method of placing the expected benefits of a transportation project in context and enabling comparisons across proposed investment projects. Consistent with standard practice, the benefits and costs were examined over the first 25 years of operation of the new rail bypass route (in addition to the upfront capital expenditures needed to complete the project). This section provides a summary of the assumptions and methodology used in the analysis.

It was assumed that the capital costs would be incurred during a three year construction period (2007 to 2009) and that the project would be in operation starting in 2010. While the actual alignment of the project is still being evaluated, the preliminary cost estimates documented in the PB Consult work for Maryland DOT were for $2.5 billion in construction/capital costs, assumed to be spent equally throughout the construction period.[26] Furthermore, it was assumed that the operating and maintenance costs would be 3 percent of the capital costs annually ($75 million).

This analysis captured the projected benefits for the 25-year period between 2010 and 2035. The total benefits are composed of those to existing freight rail operators, shippers, highway users, Amtrak travelers, and the supply chain benefits to industries

[25] If the data is readily available, an alternative approach would use the business output per Supply Chain Type™ combined with data from the Transportation Satellite Accounts to more accurately reflect how modal improvements (rail, highway, marine, air) are linked to industries.

[26] It is important to view these costs as preliminary as actual costs could vary significantly once the actual alignment is chosen and more detailed engineering work is completed.

and the economy as explained earlier in the report. This figure amounts to approximately $279 million in the year 2010, increasing to $693 million by 2035.

The costs and the benefits were discounted to the year 2006 using a 6 percent discount rate. As shown in Table 8.4 below, the analysis indicates that the national benefits of the proposed system outweigh the costs by a factor of 1.6 to 1. With a total discounted cost of approximately $3 billion for the system, and total discounted benefits of $4.7 billion, the net present value is $1.68 billion. These values reflect all of the benefit concepts used in this test case study of the analytical framework, shown in the last column of the table.

**Table 8.4 Benefit/Cost Ratios**

| | Maryland Benefits Only (No Supply Chain Benefits Included) | National Benefits (Excluding Full Highway User Benefits And Supply Chain Benefits) | National Benefits (Excluding Supply Chain Benefits | Total National Benefits |
|---|---|---|---|---|
| Freight Rail Operators | $270,229,331 | $270,229,331 | $270,229,331 | $270,229,331 |
| Shipper Costs | $1,052,304,268 | $1,655,796,822 | $1,655,796,822 | $1,655,796,822 |
| Amtrak | $176,187,771 | $625,621,147 | $625,621,147 | $625,621,147 |
| Highway Benefits | $564,591,640 | – | $873,653,722 | $873,653,722 |
| Supply Chain Benefits | – | – | – | $1,303,373,082 |
| Total Benefits | $2,063,313,010 | $2,551,647,300 | $3,425,301,022 | $4,728,674,104 |
| Total Costs | $3,046,338,138 | $3,046,338,138 | $3,046,338,138 | $3,046,338,138 |
| **B/C Ratio** | **0.7** | **0.8** | **1.1** | **1.6** |

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics.

Note: The three definitions of national benefit differ in the breadth of coverage as shown in the table.

Table 8.4 also presents how the results vary depending on the perspective in viewing the project's benefits from a regional versus national standpoint, as well as accounting for added benefits such as highway travel time and supply chain benefits to industries. While combining all of the benefits at the national level results in a favorable 1.6 B/C ratio, analyzing only the statewide benefit results (and without supply chain benefits) produces $2.1 billion of benefits, a figure outweighed by costs (B/C ratio of 0.7).

Evaluating the three rail-related criteria (existing rail, shipper costs, and Amtrak benefits) at the national level provides a slight increase in total benefits, increasing from $2.1 billion to $2.6 billion. As a result, the B/C ratio increases to 0.8. Furthermore, adding the highway benefits at the national level ($874 million) results in benefits outweighing costs by a factor of 1.1. Finally, the last column reveals the importance of including the expected benefits to industries of reduced transportation costs. Evaluating the supply chain benefits results in a significant increase in total benefits (38 percent), and a larger B/C ratio with $1.7 billion in net benefits.

The progression of including a more complete accounting of benefits to both transportation users and the industries that benefit from more efficient goods movement reveals the importance of this analytical framework. In addition, taking a national perspective on freight investment projects is especially important considering the dispersed origin-destination pattern of goods movement. In this example, a rail bottleneck in Baltimore has larger implications for industries and shippers outside of Maryland than within the State.

**Sensitivity Analysis**

It is also important to understand the effect that methodological assumptions have on the outcome of the analysis. In particular, the mileage assumptions for average length of rail trip (and the corresponding implication to truck VMT) have a very large effect on the magnitude of benefits. Average distances for through-trips and trips with Maryland origins or destinations have an especially significant effect on the final results since it directly affects the benefits for both rail shippers and remaining highway travelers, and it indirectly alters the supply chain benefits.

The analysis made by PB Consult assumed that freight rail moving through the state would travel on average 750 miles, while freight rail originating or terminating in the state would travel 500 miles. These numbers are higher than the average trip lengths estimated from 2002 Commodity Flow Survey data for Maryland freight trips (500 miles for trips through the state and 300 miles for trips with origins or destinations within the State). For trips originated/terminating in Maryland, the CFS' shipment characteristics for the State reveal an average trip distance of approximately 300 miles. The original analysis assumption of 500 miles represents a significantly longer trip with corresponding impacts on the cost per ton mile of shipping and truck VMT impact.

Table 8.5 shows how the benefit/cost results vary when using the 500/750 and 300/500 average trip length assumptions. Using the scenario with 500 and 750 miles increases the expected benefits for the shippers and the highway users by approximately 63 percent (a net increase of nearly $1.6 billion), and by consequence, boosts the supply chain benefits by 55 percent ($710 million). The combined result is an increase in total benefits of 49 percent, representing nearly $2.3 billion, and a more favorable benefit/cost ratio of 2.3, compared to 1.6 for the 300/500 scenario. This comparison demonstrates the importance of testing and reporting the robustness of key assumptions and parameters. In this case, the basic story holds – benefits do not exceed costs from a Maryland state-level perspective, but when viewed from a national perspective with a full accounting of likely benefits, benefits are estimated to exceed cost by two to three times.

**Table 8.5 Sensitivity Analysis**

| Benefit | Scenario 1: 750/500 | Scenario 2: 500/300 | % Difference |
|---|---|---|---|
| Freight Rail Operators | $270,229,331 | $270,229,331 | 0.00% |
| Shipper Costs | $2,694,157,018 | $1,655,796,822 | 62.70% |
| Highway Travelers | $625,621,147 | $625,621,147 | 0.00% |
| Amtrak Users | $1,422,398,587 | $873,653,722 | 62.80% |
| Supply Chain | $2,013,629,007 | $1,303,373,082 | 54.50% |
| Total Benefits | $7,026,035,090 | $4,728,674,104 | 48.60% |
| Total Costs | $3,046,338,138 | $3,046,338,138 | – |
| **Benefit/Cost** | **2.31** | **1.55** | **48.60%** |

Source: Baltimore Rail Studies by PB Consult for Maryland DOT and Cambridge Systematics.

# 9 Generic Framework Forms

This chapter presents sample formats that can be used to summarize analysis inputs and outputs. All of these sample tables also appear and are discussed elsewhere in the guidebook.

## 9.1 Multimodal Project Scenario Input Formats

### Table 9.1 Example of Findings from Transportation Analysis

| | Truck | Rail | Air | Sea |
|---|---|---|---|---|
| **System Performance Impacts**<br>• Enlarged Vehicle Capacity (TEUs or tons per vehicle)<br>• Enlarged Line or Terminal Capacity (Vehicles per hour)<br>• Increased Schedule Frequency<br>• Reduction in Recurrent Interchange or Bottleneck Delays<br>• Reduction in Non-Recurrent Incident Delays<br>• Improved Safety | | | | |
| **System Throughput Changes**<br>• Predicted Change in Throughput Volume | | | | |
| **Shipper Impacts**<br>• Reduced Transport Costs<br>• Reduced Logistics Costs<br>• Improved Productivity<br>• Improved Terminal Access<br>• Enlarged Delivery Market Area Access | | | | |

## 9.2 Economic Impact Output Reports

**Table 9.2 Example of Macroeconomic Impact, Detailed Measures**

| Measure of Economic Growth | National | Local/Region |
|---|---|---|
| Business Output | $ xxx | $ xxx |
| GDP or Value Added | $ xxx | $ xxx |
| Wage Income | $ xxx | $ xxx |
| Jobs | x,xxx | x,xxx |
| Exports | $ xxx | $ xxx |
| Imports | $ xxx | $ xxx |

**Table 9.3 Example Summarizing Macroeconomic Impact Measurement by Category of Affected Party**

| | National | | Local/Region | |
|---|---|---|---|---|
| | Value Added | Wages | Value Added | Wages |
| Direct Effect (Shipper) | $ xxx | $ xxx | $ xxx | $ xxx |
| Indirect Effect (Suppliers) | $ xxx | $ xxx | $ xxx | $ xxx |
| Induced Effect (Income Respending) | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |
| Business Income | $ xxx | $ xxx | $ xxx | $ xxx |
| Local Use | $ xxx | $ xxx | $ xxx | $ xxx |
| Exports | $ xxx | $ xxx | $ xxx | $ xxx |
| Imports | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |

## Table 9.4 Example Summarizing Macroeconomic Impact Measurement by Industry

| Industry/Commodity Shipped | National | | Local/Region | |
|---|---|---|---|---|
| | Value Added | Wages | Value Added | Wages |
| Oil & Gas Extraction | $ xxx | $ xxx | $ xxx | $ xxx |
| Mining & Support Activities | $ xxx | $ xxx | $ xxx | $ xxx |
| Utilities | $ xxx | $ xxx | $ xxx | $ xxx |
| Construction | $ xxx | $ xxx | $ xxx | $ xxx |
| Food Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Beverage & Tobacco Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Textiles | $ xxx | $ xxx | $ xxx | $ xxx |
| Apparel Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Leather & Allied Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Wood Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Paper Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Printing & Related Support Activities | $ xxx | $ xxx | $ xxx | $ xxx |
| Petroleum & Coal Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Chemical Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Plastics & Rubber Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Nonmetallic Mineral Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Primary Metal Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Fabricated Metal Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Machinery Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Computer & Electronic Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Electric Equipment, Appliances, etc. | $ xxx | $ xxx | $ xxx | $ xxx |
| Transportation Equipment | $ xxx | $ xxx | $ xxx | $ xxx |
| Furniture & Related Products | $ xxx | $ xxx | $ xxx | $ xxx |
| Miscellaneous Manufacturing | $ xxx | $ xxx | $ xxx | $ xxx |
| Wholesale Trade | $ xxx | $ xxx | $ xxx | $ xxx |
| Retail Trade | $ xxx | $ xxx | $ xxx | $ xxx |
| Transportation | $ xxx | $ xxx | $ xxx | $ xxx |
| Mail, package delivery & warehousing | $ xxx | $ xxx | $ xxx | $ xxx |
| Movie, Broadcasting, Sound Recording | $ xxx | $ xxx | $ xxx | $ xxx |
| Internet & Data Processing Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Monetary, Financial, & Credit Activity | $ xxx | $ xxx | $ xxx | $ xxx |
| Insurance | $ xxx | $ xxx | $ xxx | $ xxx |
| Real Estate | $ xxx | $ xxx | $ xxx | $ xxx |
| Rental & Leasing Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Professional, Scientific, Technical Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Educational Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Health Care & Social Services | $ xxx | $ xxx | $ xxx | $ xxx |
| Accommodations, Eating & Drinking | $ xxx | $ xxx | $ xxx | $ xxx |
| Repair, Maintenance | $ xxx | $ xxx | $ xxx | $ xxx |
| **Total** | **$ xxx** | **$ xxx** | **$ xxx** | **$ xxx** |

# 9.3 Multimodal Benefit Assessment Reports

### Table 9.5 Example of Multimodal Benefit Accounting

Net Present Value of Benefit Stream

| | by mode | Pass Car/ Lt.Truck | Truck Freight | Rail Freight | Bus/Rail Transit | Air Transport | Water Transport |
|---|---|---|---|---|---|---|---|
| (A) | Cost of Transport | x | x | x | x | x | x |
| (B) | Cost of Time Delay | x | x | x | x | x | x |
| (C) | Cost of Accidents | x | x | x | x | x | x |
| (D) | User Logistics/Prod Cost | x | x | x | x | x | x |
| (E) | Personal Time | x | x | x | x | x | x |
| (F) | Social & Environmental | x | x | x | x | x | x |
| (G) | Net Inward Investment | x | x | x | x | x | x |
| -- | Capital Cost of Project | x | x | x | x | x | x |
| -- | Operating Cost of Project | x | x | x | x | x | x |

| Benefit Concept | Definition | Net Benefit (Benefit-Cost) | Ratio (Benefit-Cost) |
|---|---|---|---|
| Transport System Efficiency | = A+B+C | x | x |
| Transport User Cost Savings Benefit | = A+B+C+D | x | x |
| Total User Benefit | = A+B+C+D+E | x | x |
| Total Social Benefit | = A+B+C+D+E+F | x | x |
| Total Regional Income Benefit | = A+B+C+D+F+G | x | x |

# 10 Toolbox

This section provides an overview of available tools and methods that can be used in carrying out elements of the Analysis Framework presented in this guide. It is important to note that nearly all of the available tools and methods were designed for only one or two modes of freight transportation, though some of them can be applied together, and others can be adapted for use in analysis of multiple modes.

## 10.1 Freight Network and Terminal Performance

**Overview.** Transportation network and terminal performance models are a class of tools that forecast how different types of investments and different patterns of traffic affect the functional operating capacity of transportation facilities. They generally focus on capacity, speed, cost, and reliability characteristics of the facilities. Nearly all of these tools are specific to an individual mode of freight transportation (truck, rail, air, sea). The truck and rail models tend to focus on network performance, while airport and marine port models tend to focus on terminal or port facility performance. Still, they can be used to assess effects of improving a single surface mode, or to assess effects of improving access via a surface mode to an air or marine port facility.

For example, such models can address issues such as: a) how changes in road design, and shifts in the truck portion of traffic, will affect highway speed and throughput; b) how changes in truck-to-ship or rail-to-ship loading systems can affect speed and functional capacity at marine ports; and c) how changes in rail car classification yards, double-stacking and short-line interchange can impact effective railroad speed and capacity.

**Highway Network Models.** Many projects, even if not specifically a highway improvement, will have repercussions on the highway system. For example, adding capacity and improving service to marine, rail, and aviation facilities can reduce the number of truck trips needed and therefore will have a secondary impact to the remaining auto and truck travelers in the form of reduced highway congestion. To capture these effects and the benefits from adding capacity to the highway system, some form of highway travel demand models are most frequently used.

For highway investments, the most common models are either urban area or statewide travel demand models, with full highway network data. Separate truck models within highway network models are common to many states and MPOs. Whether a traditional four-step model of trip generation, trip distribution, mode choice, and trip assignment, or a simpler sketch-planning model, highway travel performance metrics in terms of highway volumes, speeds, travel time saved, operating cost changes, and safety effects are needed to quantify and monetize the benefits on the highway system.

**Rail System Models.** Average time and cost impacts on rail carriers and shippers can be calculated based on rail carrier cost and service simulation models.

The *Uniform Rail Costing System* (Surface Transportation Board) can estimate the changes in shipper productivity associated with rail system performance changes. The URCS model uses data on average carrier cost and performance measures to estimate the cost of providing service, so it can estimate how a change in facility capacity or speed (affecting rail cars per day) would translate into average shipper dollar savings per ton-mile.

Other models can be used to estimate how a given rail infrastructure improvement would actually change volumes, speeds, and reliability. While the data is often proprietary to the railroads, there are some generally recognized software tools. *Rail Traffic Controller* (Berkeley Simulation Software), *RAILS 2000* (CANAC/Savage Industries), and *RAILSIM* (Systra) are all forms of simulation systems used by railroads to prioritize routing of trains through the network, identify conflicts and measure effectiveness. Besides the simulation systems, there has also been some work on "parametric rail capacity models" that develop capacity curves for various operating characteristics and identify areas with capacity constraints.

**Terminal Models.** One of the most critical issues in analyzing performance impacts of investments in non-highway modes is the inconsistent and often illusory nature of capacity measurement in these modes. In the case of marine terminals and rail terminals/mainlines, operating practices and technology have as significant an impact on capacity estimates as do apparent physical capacity observations. There are, however, a variety of operational simulation tools (e.g., airport and marine terminal simulation models and rail operational simulations) that are used extensively in these industries to estimate capacity implications of alternative operating scenarios.

There are several variants of airport capacity models, which estimate of the capacity of runway systems and the level of delay that they present when faced with alternative demand levels. These include *TAAM (Total Airport and Airspace Modeler)* system, the *Airfield Capacity Model (ACM)* from MITRE Corp., the FAA's *Airport and Airspace Simulation Model (SIMMOD)*, and the *LMI Runway Capacity Model* from MIT. There is also the *ACATS (Airport Capacity Analysis Through Simulation)* model, which is an attempt to improve on the ACM framework.

Many port models have been refined by university researchers. These models typically account for both passenger and freight traffic, recognizing local differences in types of freight (bulk, break bulk, and containers), mix of ship characteristics, water depth, and wave motion, and positions of terminals. See for example: "The Seaside Port Capacity: A Synthetic Evaluation Model," G. Malavasi and S. Ricci, University of Rome "La Sapienza," published by Wessex Institute, WIT *Transactions on the Built Environment*, Volume 79. Also, "An Interactive Port Capacity

Expansion Simulation Model," C. S. Park and Y. D. Noh, *Engineering Costs and Production Economics*, Volume 11, Issue 2, 1987.

## 10.2 Modal Diversion and Logistics Cost Models

**Overview.** Modal Diversion models forecast how freight movements shift in response to changes in the availability, cost and/or time performance of available modal alternatives. Most modal diversion models used in transportation facility planning are focused on truck-rail-intermodal options because there are very real tradeoffs that shippers face when considering ground transportation options for medium and long distance travel. On the other hand, air and marine options focus more exclusively on long distance shipping and offer more distinctly different cost, performance, and availability features.

**Total Logistics Cost Models** predict how shippers respond to changes in the costs of modal and service alternatives. They actually estimate the total logistics cost of shipping, including direct transportation expense and inventory cost associated with modal lot sizes and service profiles. The models assume that customers (shippers) select the lowest cost option, and they depend on information about logistical factors in transportation and industry. Shipments are assigned to one mode or another, while allowing for probability uncertainty associated with inventory risk, carrier performance or unmeasured factors. Sometimes these models are based on detailed commodity-specific data. Other times, the models may be simple spreadsheet tools to estimate tons switching mode and resulting cost and travel time differences under different project assumptions.

*Intermodal Transportation and Inventory Cost Model (ITIC)* is a freight mode choice model from Federal Highway Administration's Office of Freight Management and the Federal Railroad Administration. It attempts to calculate the logistics cost and decision tradeoffs seen by shipper logistics managers and then assigns the truck/rail diversion to alternatives that minimizes total logistics cost. It is based on an earlier model developed for FRA in 1995. (See *Intermodal Transportation and Inventory Cost Model: Highway-to-Rail Version*, U.S. DOT, FRA, and FHWA, December 2004; also Transmode Consultants, Inc., *Truck-Rail, Rail-Truck Diversion Model: User Manual*, developed for U.S. DOT, Federal Railroad Administration, 1995.)

*Spreadsheet Logistics Model* developed by MIT estimates the truck/rail mode choice for 48 typical types of customers. This is done on the basis of given customer characteristics (use rate and trip length), commodity characteristics (value/pound), and mode characteristics (e.g., price, trip time, and reliability) for rail, truck, and intermodal options. (See "Performance-Based Technology Scanning" Journal of the Transportation Research Forum Paper, 2002.)

Logistics cost models can also assess the cost savings of shipments using alternative different aircraft or ships (e.g., larger marine cargo ships that reduce costs per ton of goods). For air and marine facilities, models are most commonly simply matters of terminal volume/capacity measurement and forecasting (since obviously those modes do not have fixed right-of-way networks as exist for roads and rail).

**Market Share models** are an alternative predictor of freight shipper choices. They do not estimate logistics costs. Instead, they are based on a statistical correlation between modal performance factors and traffic capture (revealed-preferences), and they then project traffic swings when relative performance changes. Stated-preference models have similar purposes but are developed statistically from structured interviews with freight transportation buyers about the tradeoffs they would make if faced with hypothetical choices. A statistical process is then applied to these responses to infer decision points and probable traffic diversions in response to changes in competitive service offerings.

For instance, the *Intermodal Diversion Model* from Global Insight, originally referred to as the "Reebie Intermodal Diversion Model," estimates truck-rail diversion based on a combination of 1) the Uniform Rail Costing System, 2) TRANSEARCH commodity-flow database, and 3) a demand elasticity model calibrated from historical carrier price and volume data. The elasticities distinguish price sensitivity by traffic type, geographic region, and commodity group, and the model forecasts the specific freight flows that would likely be diverted to rail given changes in railroad or intermodal service characteristics.

## 10.3 Cost and Access Benefit Calculations

**Overview.** Given direct travel performance impacts and mode switching impacts estimated by the two preceding types of models, it is a relatively straightforward process to assign dollar values to the changes in travel time, cost of shipping by mode, operating costs, schedule reliability, and other logistics factors. In addition, it is also possible to estimate the value of improvements in access from ports or terminals to markets.

**State or Regional Highway Models** calculate the dollar value of time, cost, safety, and reliability improvements associated with changes in highway system performance. *Surface Transportation Efficiency Analysis Model (STEAM)* is a benefit analysis tool for sketch planning of roadway transportation programs. It does not include roadway network features, but rather calculates traveler benefits at the regional or corridor levels. It calculates the economic value of benefits in travel time, accidents, non-fuel operating costs, and fuel costs. It can also distinguish eight commodity types and four vehicle types, and also account for air quality benefits.

*ITS Deployment Analysis System (IDAS)* is a related system that assigns values of time, and parameters for operating costs, emissions, and accident rates. IDAS also estimates benefits due to improved reliability based on traffic volumes and a reduction in non-recurring delay. For freight movement in heavy traffic volume areas, reliability benefits can be a key component of the analysis. IDAS functions through direct interaction with a travel demand model network (see *State or Regional*

*Highway Network Models* below) so the analysis can be conducted for specific links or zones in the model allowing the user much flexibility in identifying specific facilities, corridors, or regions for conducting the analysis. IDAS benefits analysis can be conducted by allowing IDAS to conduct the traffic assignment using network and zone inputs from an external model or it can use the results of a traffic assignment conducted by an external travel demand model and input into IDAS as a fully loaded network for benefits analysis.

*State or Regional Highway Network Models* operate at the more detailed link and node (network) level to calculate time and cost savings associated with changes in specific highway network inter-connectivity features or major improvement in connections between highways and special generators such as ports or intermodal rail terminals. Results of highway models can be translated into dollar values using values as shown in the *AASHTO Red Book*, or using broader factors that are discussed more fully in the *Caltrans Benefit Cost Guide* (discussed later in Section 10.5).

**Railroad Models** likewise calculate the dollar value of improvements in rail system performance. *RAILDEC – Railroad Decision Model* from the Federal Railroad Administration is a family of software tools designed to evaluate the economic benefits from proposed rail-related infrastructure benefits. It is designed for use by metropolitan planning organizations (MPOs) and state DOTs to conduct benefit-cost analyses for railroad-related projects and highway-rail interactions (including grade crossings). It also operates within a risk/uncertainty analysis framework.

**Rules of Thumb** on highway and rail freight improvements can also be used to assign money values to freight transportation benefits. Sources include:

- *Freight Transportation: Improvements and the Economy*, U.S. DOT, FHWA, Washington, D.C., June 2004.
- *Economics Effects of Transportation: The Freight Story*, ICF Consulting and HLB Decision Economics for the FHWA; January 2002.
- "Comparison of External Costs of Rail and Truck Freight Transportation" by David Forkenbrock, *Transportation Research Part A*, Volume 35, p. 334, 2001.

**Market Access Models** estimate how business activity (generating freight demand) can shift among locations when new freight routes and ports open up or improve access to areas that were previously not attractive as freight generators. For instance, a new international gateway (such as an international marine port, airport, or border facility) or a new link between ports and markets (such as a rail line or highway link) can bring enhanced productivity at a national level and economic growth to depressed areas that would not otherwise see such growth. Whereas network performance and modal diversion models estimate cost savings for freight between fixed origins and destinations, a market access model offers a complementary measure of additional net income growth that may be beyond the cost savings.

The *Local Economic Assessment Package (EDR-LEAP)* estimates the magnitude of potential opportunities for regional business expansion and attraction resulting from highway or rail projects that affect a community or region's market access and connections to outside areas. This may include access to customer/ supplier delivery markets, transportation terminals (including airports, marine ports, and intermodal rail transfer facilities), international borders or industrial centers. These types of business access benefits are in addition to the simple travel time and cost savings benefits that are traditionally recognized in transportation planning models. A predecessor model that focused on highway connectivity was called *Highway Economic Opportunities Model (ARC-Opps or HWY-Opps).* This type of tool can be used as an adjunct to REMI, REDYN or Global Insight models to forecast long-term economic impacts of connectivity improvements. It is also included as part of the TREDIS framework for benefit cost evaluation, discussed later.

Background material on methods for measuring and valuing market access effects of truck transportation improvements are included in NCHRP Report 456 (Guide for Assessing Social and Economic Effects of Transportation Projects) and in NCHRP Report 463 (Economic Implications of Road Congestion). Discussion of highway connectivity to airports, marine ports, and intermodal terminals is discussed in reports of the Appalachian Regional Commission (Handbook for Assessing Economic Opportunities from Appalachian Development Highways, Economic Development Research Group with Cambridge Systematics, 2001).

# 10.4 Economic Simulation Models

**Overview.** Economic impact models are frequently used to convert direct economic effects into broader regional/macroeconomic impacts on measures such as employment by industry, gross regional/state product, and personal income. This can include direct benefits from savings in business costs for current shipping patterns, and/or economic growth benefits from improved market access. The most frequently used models are dynamic, time-series economic simulations. Sometimes, static input-output models are applied in conjunction with price elasticity response calculations to accomplish these same results. Application of these various types of models for multimodal transportation projects are summarized in NCHRP Synthesis Report 290, *Current Practices for Assessing Economic Development Impacts from Transportation Investments*, NCHRP Synthesis of Practice, TRB, 2000. Links to various economic simulation models are offered on the web site of the TRB Committee on Transportation and Economic Development (www.tedcommittee.com).

**Economic Forecasting Models** have been developed by both commercial vendors (e.g., Global Insight, Economy.com) and non-commercial economists (often universities) to project future economic trends either for entire regional economies or individual industries. Various OECD and UN products also provide industrial analysis forecasts at a more global level. These projections can be useful to project future demand for transportation services and help identify potential capacity constraints, and they can also be used to show historical relationships between transportation infrastructure/investment (capital stock) and economic growth (or industrial performance). However, these latter types of models do not provide the necessary "levers" to be sensitive to the nuances of modal service changes (e.g., scheduling, reliability, capacity, or accessibility) associated with individual freight transportation projects.

**Input/output (I/O) models** such as IMPLAN and RIMS-II are essentially variations of accounting tables that track the buying/selling interrelationships between industries within given regions. They reflect forward and backward linkages in the flow of money, associated with business suppliers and consumer spending. They can thus capture the full economic impacts (including multiplier effects) derived from changes in demand or output in a given industry. However, traditional I/O models alone are not designed to easily estimate how impacts vary over time or capture the business cost effects of transportation improvements. The I/O models have been used together with industry-specific cost response or logistics models to calculate the broader growth effects that transportation projects can have on various industries.

**Regional Simulation Models** include both "General Equilibrium" and "Structural Economic Simulation" models such as the REMI, REDYN, Global Insight, Inforum, FAIR, and REAL models. They combine features of input/output models with the long-term elements of forecasting models, to forecast the economic growth trajectory of industries between multiple regions under baseline conditions and alternative scenarios. These models can and have been used to forecast the spatial restructuring of business activities resulting from changes in comparative business costs among regions. Regional Simulation Models still require travel model results to determine the direct transportation cost effect, and they also require exogenous analysis to capture the full range of changes in market access and associated economies of scale that can also result from major transportation projects. Of note, these models forecast changes in regional growth as shares of a closed national economy, so they do not allow for changes in international trade (which is important for projects serving ports/ borders).

**Production Function Models** encompass a class of industry-specific equations and tools that forecast how businesses evaluate supply chain and production options to optimize size, locational dispersion of siting, production processes, and distribution channels. They are typically sensitive to relative changes in market prices and costs of capital, labor, and transportation.

## 10.5 Decision Support Tools

**Overview.** Project evaluation has several major elements. It is desirable to estimate costs and benefits of any major freight transportation project over a suitable timeframe and compare them to alternative plans of action, considering financial and social, public and private benefits and costs. However, techniques differ in breadth of coverage and consideration of incidence of these factors.

**Benefit Cost Analysis (BCA)** is fundamentally a comparison of all of the positive and negative impacts of a project expressed on a consistent basis in terms of net present values. While this is clearly an attractive methodology, one of the major criticisms of BCA is that some of the impacts are not measurable in dollar terms. As a result, BCA studies frequently estimate the total monetary value of benefits and costs for travelers and transportation agencies, leaving out other positive and negative impacts that are not measurable in money terms (which are then dismissed as immeasurable "externalities"). Some studies have attempted to convert other impacts into monetary terms through surveys that derive "willingness to pay" for impacts ("stated-preference") or observations of actual choices as reflected in property values.

Another limitation of BCA is that it is designed to aggregate all benefits and all costs, without regard to their incidence. In the case of major freight projects, this means that it ignores the different roles of public agency and private investment functions, which need to considered in evaluating opportunities for "win-win" propositions in public-private partnerships. However, it is possible to evaluate the incidence of benefits and costs by conducting BCA separately for subgroups that may include private carriers, various industries, and the general public. Such an approach is recommended for the analysis framework in this report.

**Multimodal BCA.** There are several forms of multimodal models for benefit-cost analysis. *TransDec: Transportation Decision Analysis Software*, developed as part of NCHRP 20-29 (2), is designed for evaluation of transportation investment decisions spanning multiple modes of ground transportation. This package is notable because it is explicitly concerned with freight as well as passenger transportation. It structures a process of evaluating transportation investments on the basis of multiple objectives, such as improved accessibility, connectivity, cost-effectiveness, resource impact, and economic growth. The system is designed for comparing multiple alternatives, with minimum performance thresholds.

*TREDIS: Transportation Economic Development Impact System* is a web-based evaluation system that is most notable for its distinctions between both freight and passenger benefits, and its simultaneous coverage of roadway, railroad, aviation, and maritime transportation. This economic analysis system evaluates how changes in transportation costs and accessibility relate to the operating requirements of various industries and resulting productivity and growth. It works with the REMI model, REDYN model or IMPLAN model with cost response factors, and then processes results to show benefits and costs from alternative perspectives.

Three web sites that contain guidelines for conducting multimodal transportation benefit cost analysis are:

1. *Internet Guide to Transportation Benefit Cost Analysis*, developed by ASCE and maintained by Caltrans at: www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost;

2. Transport Canada Guide to Benefit-Cost Analysis at: www.tc.gc.ca/finance/bca/en/bca.pdf; and

3. *FHWA Cost-Benefit Forecasting Toolbox* at: www.fhwa.dot.gov/planning/toolbox/costbenefit_forecasting.htm.

**Internal Rate of Return.** The internal rate of return (IRR) is the discount rate that makes the Net Present Value (NPV) of all cash flows equal zero. It is particularly useful for investments that require and produce a number of cash flows over time. Technically, IRR is a discount rate: the rate at which the present value of a series of investments is equal to the present value of the returns on those investments. As such, it can be found not only for equal, periodic investments but for any series of investments and returns. This makes IRR an attractive approach in the private sector. However, this method is problematic, as it assumes that all of the intermediate cash flows can be discounted/reinvested at the IRR. This is particularly unrealistic when the IRR is very high. This method is also sensitive to the sequencing and timing of investments and returns.

**Cost-Effectiveness Analysis (CEA)** differs from BCA in that it does not seek to simultaneously evaluate all positive and negative impacts, and it does not require that all positive and negative effects be boiled down to a common measure of dollars. Rather, CEA compares the effectiveness of project alternatives in achieving various individual indicators of desired benefits (such as reducing congestion and improving air quality and freight flow). However, CEA is limited as it examines single dimensions of impact that may affect different parties (travelers, shippers, or transportation providers), and it still does not differentiate coincidence of costs.

**Multiple Criteria Appraisal (MCA)** is most popular in Europe as a more comprehensive alternative to the use of BCA. It provide a means of considering the wider issues of qualitative and quantitative benefits and costs, as well as distribution and equity of their incidence, in a unified framework based on rating criteria.

*Guidance on Methodology for Multimodal Studies (GOMMs)* is a tool that implements the UK Treasury's Green Book for appraisal of alternatives for public sector funding as it applies for transportation projects regardless of mode. The tool lays out all the various considerations of accessibility, economic, environmental and distributional impacts through use of Appraisal Summary Tables (ASTs). There is a worksheet for rating "Transport Economic Efficiency" from the perspective of consumers, business, private sector providers, and developers. There are also separate worksheets for rating "Public Accounts" from the perspective of Local and Central Governments.

*Scottish Transport Appraisal Guide (STAG)* is a variant of GOMMS used in Scotland. It also builds on the concept of Appraisal Summary Tables, with a concise rating form for assessing project alternatives in terms of seven factors: 1) social and economic context, 2) planning objectives and measures of performance along them, 3) project rationale, 4) fit with land use and other policies, 5) implementability, 6) efficiency for conventional transport user benefits and costs, and 7) economic impacts in terms of employment and GDP (gross domestic product – a measure of economic output).

# 10.6 References and Links

**Multimodal Analysis: Freight**

NCHRP 8-42, *Guidebook for Assessing Rail Freight Solutions to Roadway Congestion*, Global Insight and Economic Development Research Group for the Transportation Research Board, 2006.

**Multimodal Analysis: General**

*Internet Guide to Transportation Cost Benefit Analysis*, Caltrans, 2005, http://www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost/index.html.

NCHRP Research Results Digest 258, *Development of a Computer Model for Multimodal, Multicriteria Transportation Investment Analysis*, Texas Transportation Institute for the Transportation Research Board Washington, D.C., 2001, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_258.pdf#search=%22NCHRP%20Report%20258%22.

NCHRP Synthesis Report 290, *Current Practice for Assessing Economic Development Impacts from Transportation Projects*, Economic Development Research Group, Inc for the Transportation Research Board, Washington, D.C., 2000, http://www.edrgroup.com/pages/pdf/synth290.pdf.

Transportation Research Circular 477, *Assessing the Economic Impact of Transportation Projects: How to Match the Appropriate Technique to Your Project,* Weisbrod, G., and B. Weisbrod, Transportation Research Board, Washington, D.C., 1997, http://gulliver.trb.org/publications/circulars/circular477.pdf.

Scottish Executive, *Scottish Transport Appraisal Guidance*, 2003, www.scotland.gov.uk/library5/transport/stag.pdf.

United Kingdom Department of Transport, Labor and the Regions (DTLR), *Guidance on the Methodology for Multimodal Studies (GOMMS)*, London, England, 2003, http://gulliver.trb.org/publications/circulars/circular477.pdf.

European Commission, *Guide to Cost-Benefit Analysis of Investment Projects*, prepared for Evaluation Unit, DG Regional Policy, 2003, http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide02_en.pdf.

**Mode-Specific Guides**

Federal Aviation Administration, *FAA Airport Benefit-Cost Analysis Guidance*, Office of Aviation Policy and Plans, Federal Aviation Administration, U.S. DOT, 1999, http://www.faa.gov/airports_airtraffic/airports/aip/bc_analysis/media/faabca.pdf.

Federal Railroad Administration, *GradeDec.Net Benefit-Cost Analysis Tool*, U.S. DOT, 1998.

NCHRP 8-36, *Return on Investment on Freight Rail Capacity Improvement*, Cambridge Systematics, Inc. and Reebie Associates, Inc. for the American Association of State Highway and Transportation Officials (AASHTO), 2005, http://www.transportation.org/?siteid=30&pageid=1399.

Federal Highway Administration, *Cost-Benefit Forecasting Toolbox for Highways*. U.S. DOT, Washington D.C., 2001, http://gradedec.fra.dot.gov/.

Federal Highway Administration, *Freight: Cost-Benefit Methodology*, FHWA Freight Management and Operations, U.S. DOT, FHWA-HOP-05-060, 2005, http://ops.fhwa.dot.gov/freight/intermodal/cost_bene_meth/cost.htm.

# Appendix A. Integrating Supply Chain Benefits into Economic Analysis

## A.1 Synopsis – A Framework for Assessing the Supply Chain Benefits of Transportation Infrastructure Projects

Traditional transportation and economic impact modeling has addressed the impacts on industry somewhat irregularly, with few studies addressing exactly how businesses benefit from improved transportation. This appendix explains and quantifies the industry impacts from transportation improvements with emphasis on supply chain effects. Companies have been successfully leveraging supply chain principles for cost savings and service improvement for over 20 years. The supply chain effects of transportation improvements are a critical element of that improvement and this analysis provides needed information on the logistics (aka, second order effects) benefits to industry.

Transportation projects deliver supply chain benefits by *lowering transportation costs, by alleviating capacity bottlenecks, and by enhancing in-transit visibility.*

Shippers use *lower transportation costs* to source from less expensive suppliers, which increase their margins. They also deliver at lower costs per shipment. They operate fewer plants because they get greater market reach from each one, thereby reducing assets and increasing return on assets. They also opt for smaller shipments, which had been prohibitively expensive, and thereby decrease inventory again.

Shippers use *freed-up capacity* from fewer bottlenecks to reduce inbound variability of arrival times, which results in less inventory. Less variability allows them to reduce the size of fleets because they need fewer vehicles for peak-period congestion, as well as fewer spares. And with less variability they reduce warehouse space that held inventory that was buffering against the unreliability of inbound shipments due to potential congestion.

The secondary effects create even more benefits for shippers than these supply chain cost and service advantages. Shippers reinvest the cash savings in price reductions, thereby becoming more competitive, which increases sales and profits. They increase service levels at no cost, or at low cost, thereby increasing customer satisfaction and loyalty. And they create flexible, nimble, on-demand supply chains based on small order quantities, resulting in sustainable competitive advantage.

Supply chain benefits accrue unevenly because companies' logistics configurations vary widely. However, planners can assess the supply chain impact of individual projects by classifying the affected population of companies into six Supply Chain Types™, and quantifying the supply chain impact of projects on companies of each Type. The six categories are: Extraction, Process manufacturing, Discrete manufacturing, Design-to-order manufacturing, Distribution, and Reselling. And each type of supply chain reacts differently to an economic stimulus such as reduction in transportation cost.

Two follow-up research efforts are recommended for consideration. The first is to refine the mapping of the six Supply Chain Types to NAICS industry definitions and consider how this varies by region. The second is to develop a method for quantifying the revenue benefit of supply chain improvements.

# A.2 Why Supply Chain Effects Are Important Today

Supply chain management trends have re-shaped the way shippers manage their logistics function over the last 10 to 20 years. Supply chain management as a whole emerged as an outgrowth of distribution, followed by logistics, and then the "extended enterprise."

Three supply chain trends have dominated the agenda of supply chain professionals due to their ability to generate cost savings and improve customer service. These are strategic sourcing, lean manufacturing and distribution, and in-transit visibility.

- Strategic sourcing has become a mature and embedded process in most companies because of the cost reduction pressure placed on manufacturers as a result of our transition to a service economy and the consequent commoditization of goods. Recently, strategic sourcing has focused primarily on global sourcing and off-shoring, which has led to more imports.
- Lean manufacturing and distribution has enjoyed popularity since the Japanese auto industry overtook the American carmakers in the 1970s. Lean supply chain concepts include just-in-time (JIT) principles to reduce inventory, total quality management, and statistical process control. Extensions of the concept have led to Efficient Consumer Response (ECR) in the retailing industry, flexible manufacturing, postponement, assembly-to-order, and cross-docking. Lean manufacturing's quest for a "one-piece flow" has led to a new paradigm of "mass customization," which is predicated on smaller lot sizes and smaller shipments, and producing only what the customer wants when he or she wants it.

- In-transit visibility, which originally attracted attention as a technology investment during the Internet boom, has grown due to its capacity to improve customer service and simultaneously reduce costs. Intelligent transportation systems track vehicles, equipment, and cargo.

# A.3 How Shippers Convert Transportation Benefits into Competitive Advantage Via Their Supply Chains

Just as strategic sourcing, lean manufacturing and distribution, and in-transit visibility can lower transportation and/or logistics costs, investments in transportation infrastructure can magnify and accelerate the benefits realized by these programs.

Given lower transportation costs, shippers will set up and operate their networks more efficiently. They will:

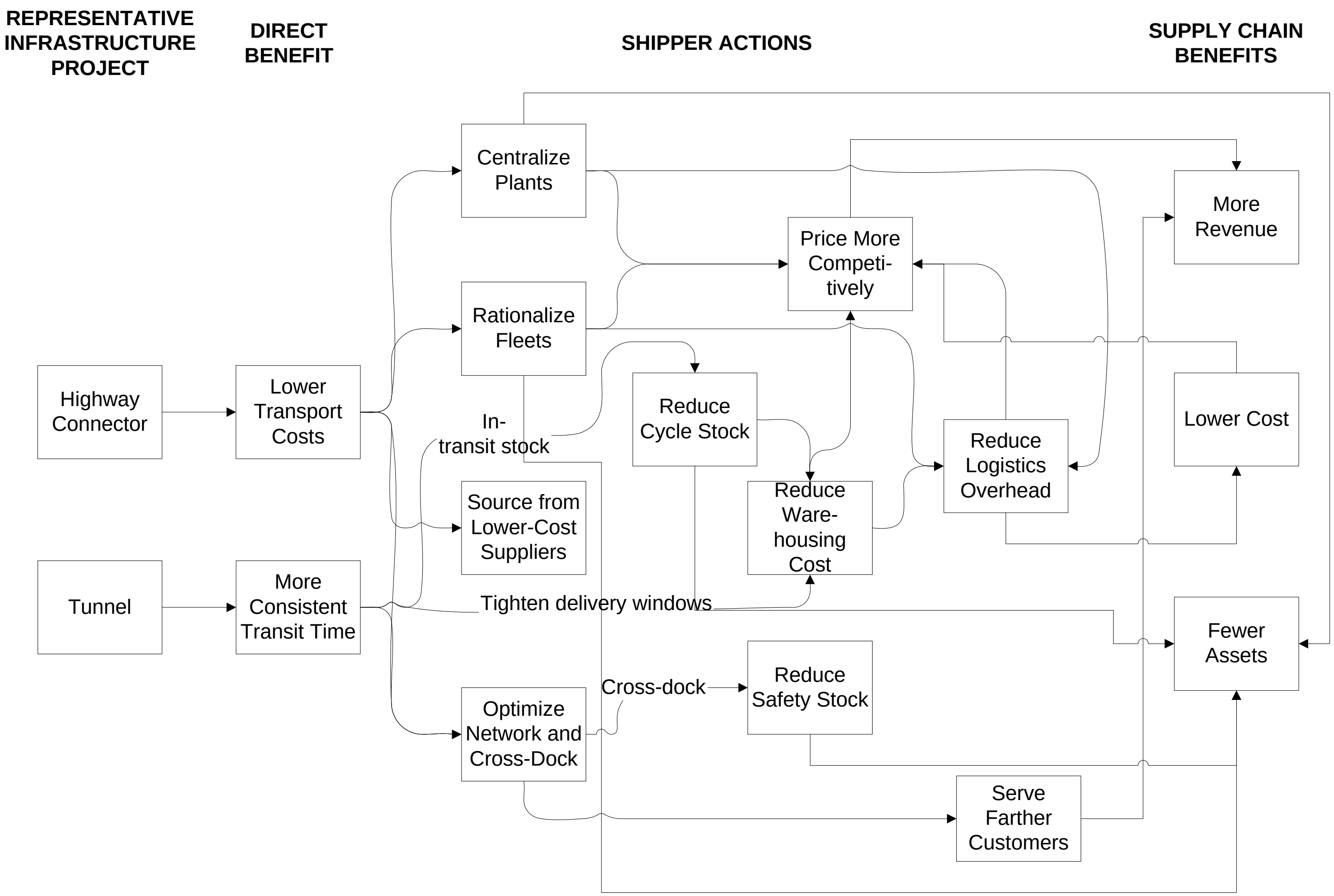
- **Source from less expensive suppliers that are farther away.** Lower transportation costs help shippers source from more efficient but more distant suppliers, and reduce shipment size and inventory, thereby creating Lean benefits.
- **Operate fewer, larger plants at the same delivered price and relocate existing plants to lower-cost areas.** Global competition has led to larger-scale manufacturing plants at lower manufactured cost per unit. Therefore, transportation costs are becoming a larger part of the site location cost equation through the delivered cost per unit (transportation represented 51 percent of logistics costs in 1984 and 63 percent in 2004[27]). Any infrastructure that lowers the cost of getting freight from one place to another supports a more efficient use of plant capacity.
- **Reduce average shipment size, adding to manufacturing flexibility.**

Given additional transportation capacity and fewer bottlenecks, shippers will create "lean" supply chains that:

- Shift warehouse stock to in-transit inventory (increase velocity of product through the chain), which further reduces warehouse operating cost, which reduces the need for logistics overhead.
- Rationalize the vehicle fleet and the warehouse labor needed to serve the same customer demand. Because shippers get more turns from the existing vehicle fleet, they need fewer vehicles and drivers. Because average transit time is reduced by eliminating bottlenecks, shippers can do more same-day and overnight cross-docking, so they can reduce warehouse space and labor. With cross-docking, they may even be able to set tighter delivery time windows and thereby reduce receiving staff.

[27] 2005 State of Logistics Report.

**Figure A.1 How Shippers Leverage Transportation Infrastructure Improvements for Supply Chain Advantage**




Source: Boston Strategies International, Inc.

Realizing the benefits from transportation improvements can take up to 24 months after the completion of an infrastructure project. In addition, companies may need to make a substantial financial investment or organizational change to achieve the benefits. A timeline of benefits would look something like this:

- *Month 3: Switch to cheaper materials.* It often takes a few months to identify alternative suppliers for a material or product
- *Month 6: Reduce inventory.* Shippers often have monthly "production, sales, and inventory" that determine when, where, and how much inventory is held.
- *Month 9: Consolidate fleet.* Based on a 12-month rolling cycle where vehicles come off lease and tags expire, creating the conditions for fleet rationalization.
- *Month 12 to 24: Consolidate facilities.* Physical consolidation will depend on budget cycles, financing, and long-term planning, and may stretch over two or more cycles.

In addition to these specific benefits, shippers obtain substantial "shadow" benefits from all of these programs in three forms. They will:

- Convert cost savings into price reductions, thereby stimulating demand and revenue growth.
- Leverage lower transportation costs to offer better service levels for the same price, OR same service level for lower price, OR higher service levels for higher price; and shorter order-to-delivery leadtimes.
- Create "on-demand" supply chains where flexible manufacturing and distribution results in less waste and more sales at higher margins by ensuring that the right product is in the right place at the right time.

# A.4 Leveraging Lower Transport Costs

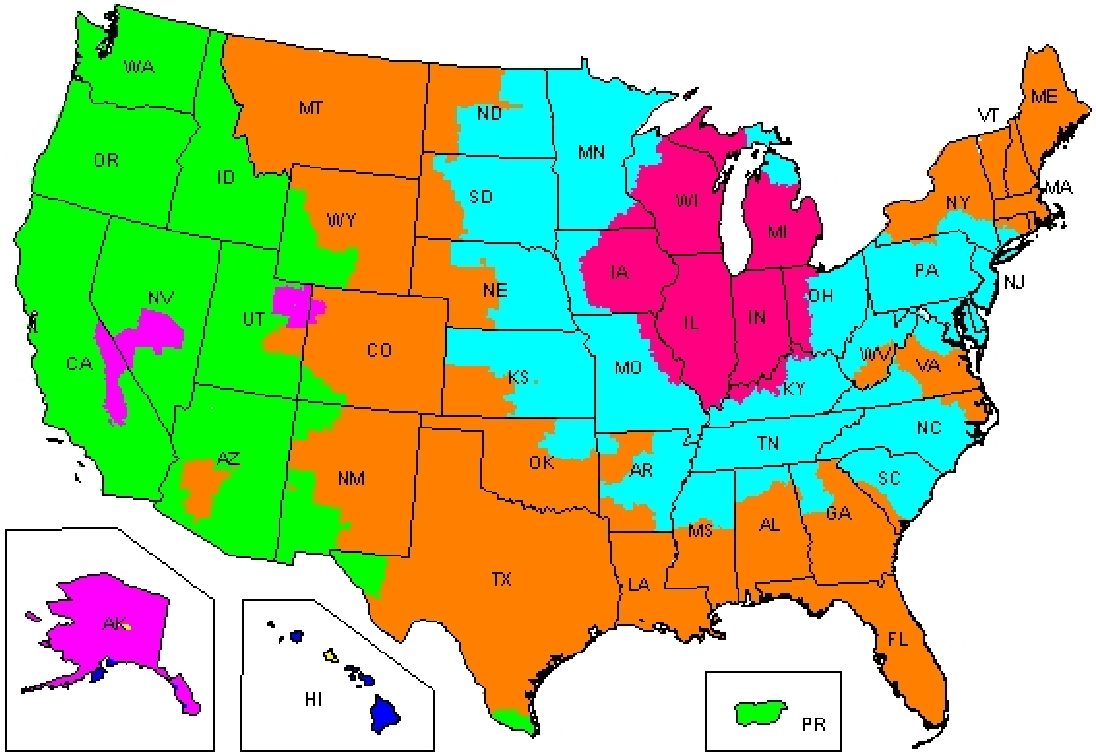
**Sourcing From Less Expensive Suppliers, Increasing Margins**

The benefits from strategic sourcing are well-documented. Often, distant suppliers can offer lower prices as economic conditions vary across regions. Furthermore, savings from global sourcing are much greater than those from domestic sourcing.

However, transportation costs usually disadvantage distant suppliers, even if their prices are lower, because transportation costs neutralize the price differences. As distance increases, the ratio of transportation cost to material or product cost increases, discouraging buyers from contracting with far-away suppliers. The farther the supplier, the greater the transportation disadvantage.

A one-day delivery range is about 600-800 miles (see Figure A.2), which is a function of the number of over-the-road hours that can be driven in a day by long-haul truckers.

**Figure A.2 Truck Delivery Zones by Number of Days from Chicago**




Source: FedEx.

Note: Each color represents one day of delivery time (red = 1 day, blue = 2 days, etc.).

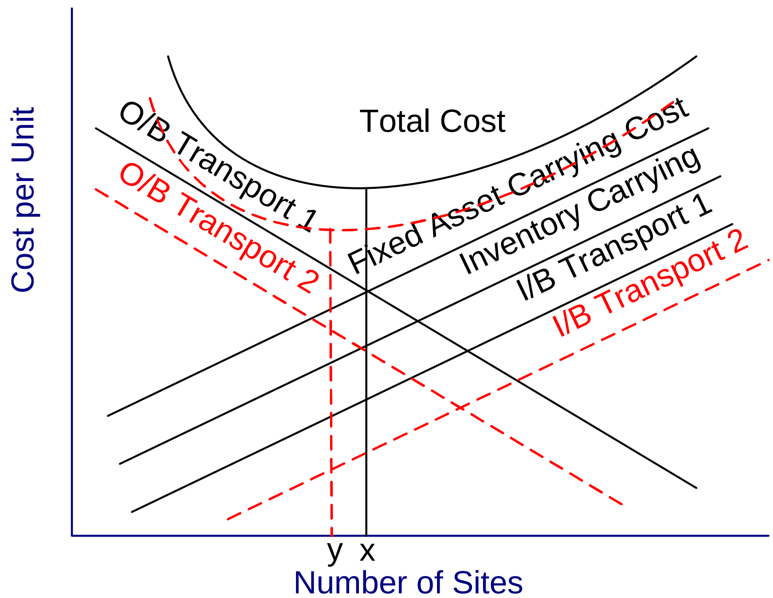
While manufacturers will eliminate potential suppliers due to their distance, lower transportation costs make those suppliers eligible and competitive. Lower transportation costs enable shippers to buy from less expensive suppliers that are farther away. The extent of sourcing savings from lower-cost transportation depends on the amount of external "spend," the savings from sourcing farther away, and the extent of the reduction in transportation cost. Lower transportation costs also allow companies to have a broader range of supplier options, and hence product differentiation. This is especially true for companies in bulk or heavy commodities such as steel, wood, paper, or furniture.

## Operating Fewer Plants, Increasing Return on Assets

When manufacturers or distributors decide how many sites they need to serve a geographical area, they balance the tradeoffs between facility operating and capital costs, which generally increase with the number of facilities, and transportation costs, which often decrease with the number of facilities.

Figure A.3 shows how the number of sites decreases as a result of a decrease in transportation costs. As the inbound transport costs decrease, the I/B cost curve shifts down. As the outbound transport costs decrease, the O/B cost curve shifts down. At the new levels of inbound and outbound cost, the Total Cost curve shifts down and to the left, resulting in the minimum part of the cost curve shifting to the left, from x to y. If inbound and outbound transport costs were identical and there were no other costs involved, the Total Cost curve would simply shift down, leaving the minimum point unchanged at x. The degree of lateral shift, and hence the potential for site reduction, depends on the proportion of asset, inventory, warehouse operating, inbound transportation, and outbound transportation costs, as well as the shape of the demand curve for each of them.

**Figure A.3 Site Location Cost Drivers**




Source: Boston Strategies International, Inc.

**Reducing Shipment Size, Decreasing Inventory**

Lower transportation costs enable shippers[28] to ship smaller shipments at the same cost that they would have spent for a larger bulk shipment[29]. Smaller shipments lower the average order quantity both on the supply and the demand side, thereby lowering the average level of inventories. Smaller shipment sizes and order quantities also create other benefits that are addressed in "Secondary Effects," including a more responsive supply chain that results in higher order fill rates and a wider product mix that results in more orders, sales, and profits.

[28] Shippers are defined here as companies that send product to another company, whereas receivers are companies that receive product that is shipped by another company. Most manufacturers are both shippers and receivers because they receive raw materials and ship finished product, so when viewed across a whole sector the distinction becomes irrelevant.

[29] Although companies usually have a mix of freight terms with their suppliers and customers, in practice shippers often pay the freight bill to the carriers and receivers pay it as part of the product price or as a separate line item on the invoice. Receivers increasingly "unbundle" the freight component, especially where they have significant purchasing power in freight, in order to have more control over the delivered cost.

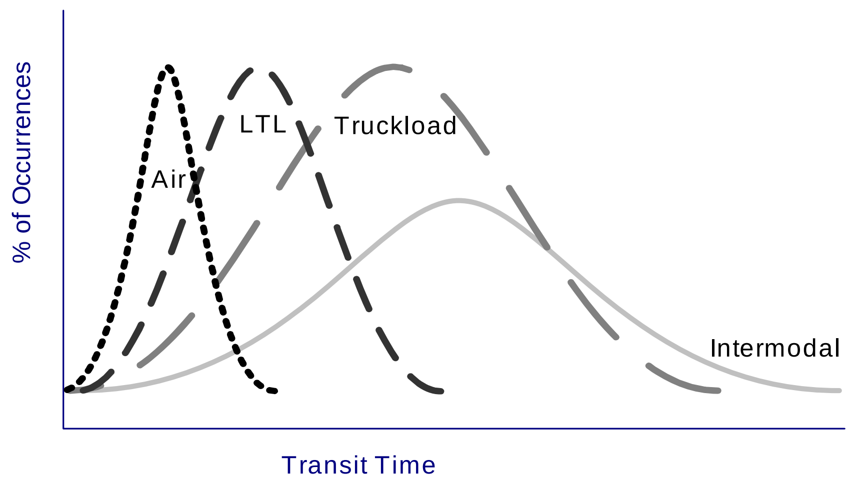
Shipment size issues primarily affect inbound transportation. Customers usually have control over shipment size and cost on the outbound side, even if they are not paying for the freight. However, it is possible that the shipper could lose sales, or his customers might decide not to place the orders, because the order cycle time is too long due to a long transportation lead time driven by consolidation into large shipment sizes.

# A.5 Leveraging Capacity from Fewer Transportation Bottlenecks

**Increasing Inbound Reliability, Resulting in Less Inventory**

Transportation bottlenecks create an alternating flow of "blocking" (excess inventory) and "starving" (stock-outs). Shippers compensate for transportation bottlenecks by holding extra inventory. By increasing the reliability of inbound leadtimes (reducing the variability of arrival times), shippers reduce the amount of safety stock they must hold. Uncertainty of supply consists primarily of transportation leadtime, and secondarily of the suppliers' requirements for production leadtime. The variability of transportation leadtime can be measured in standard deviations from the mean delivery leadtime. When there is high variation in the delivery leadtime, standard deviation is high and the bell curve is relatively flat. Intermodal traffic typically has a large degree of variability (see Figure 4). In contrast, truckload and LTL transits are usually shorter and more predictable. Air shipments are the quickest and the some would argue the most predictable (the smallest standard deviation).

**Figure A.4 Transit Time and Variability by Mode**




Source: Boston Strategies International, Inc.

Although many shippers have switched modes to achieve more predictable leadtimes, effective transportation policy that reduces bottlenecks can achieve similar reductions in variability on existing modes.

**Rationalizing Fleet and Warehouse Assets, Increasing Return on Assets**

With less variability of supply, shippers need fewer spare vehicles and fewer vehicles to handle peak demand. Spares substitute for vehicles that are in maintenance, while extra vehicles buffer against demand spikes. In addition to reducing safety stock, receivers of freight can schedule time windows and expect carriers to meet them, as well as reduce the warehouse footprint and the associated logistics overhead.

# A.6 Secondary Effects

For many companies, achieving direct cost reductions from supply chain programs is only the beginning of the economic benefit. In addition to the aforementioned benefits, shippers and receivers get additional benefits from investing savings in price reductions, increasing service levels, trimming logistics overhead, and creating additional sales with "on-demand" supply chains. Additional information on secondary effects is provided in the full technical memorandum on supply chain benefits, but given the lack of available/reliable estimates of the effects, it has been left out of this section of the report.

# A.7 Size of the Overall Supply Chain Benefit

If shippers were to aggressively pursue every benefit, a 10 percent reduction in transportation cost could create a very significant reduction in shippers' operating costs through a combination of these multipliers (see Table A.1), which are in addition to the direct transportation benefit.

Financially, shippers appear to get the most leverage from using transportation cost benefits to access lower-cost sources of supply, consolidate facilities due to greater market reach, and to reduce inventory through smaller order quantities. Therefore, infrastructure projects that help shippers improve their access to low-cost sources of supply and reduce their inventory and warehousing costs have significant supply chain leverage.

Secondary benefits, though not quantified, may be more significant than the primary benefit. Re-investment of cost savings in price reductions and increased service levels helps make companies more competitive. However, the value of "on-demand" supply chains was not estimated in this paper due to the amount of primary research that would be required to develop benefit estimates that would be acceptable to a broad range of practitioners.

**Table A.1 Rough "First-Cut" Estimate of the 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 farther 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% |
| 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 |
| | | 0.5% | 8.2% |

Source: Boston Strategies International, Inc.

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.

Companies must invest time and money to realize the full benefits made possible through transportation infrastructure improvement. Boston Strategies International survey data shows that companies that focus on improvement efforts earn four times the payback of those that make ad-hoc efforts. So while some benefits will accrue "automatically" to shippers, many will take longer and require deliberate adjustments to their supply chains.

### How to Quantify Supply Chain Benefits for Specific Types of Shippers

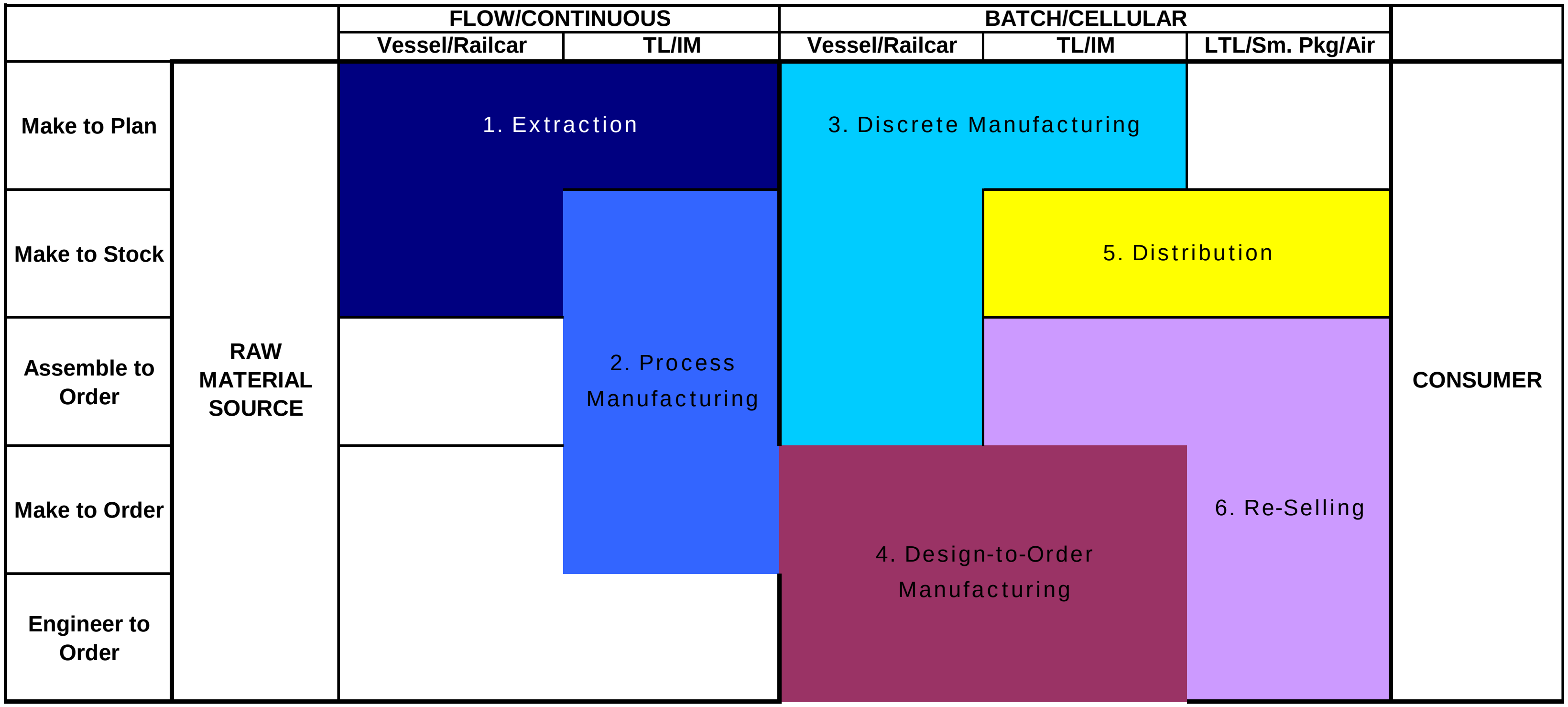
**Classifying the affected population.** Boston Strategies International's framework of supply chain types categorizes companies by their supply chain characteristics, as shown in Figure A.5. The chart identifies six unique Supply Chain Types™: 1) extraction; 2) process manufacturing; 3) discrete manufacturing; 4) design-to-order manufacturing; 5) distribution; and 6) reselling.

Four variables differentiate the types:

1. Production strategy (flow/continuous vs. batch/cellular);
2. Transportation mode (ship/railcar, truckload/intermodal, or LTL/small package/air);
3. Order trigger (make to plan, make to stock, assemble to order, make to order, or engineer to order); and
4. Breadth of coverage between the raw material supplier and the end consumer.

Companies respond differently to transportation infrastructure investments depending on their supply chain types.

**Figure A.5 Classification of Shipper Types**




Low External Spend <------------------------------------------------------------------------------ > High External Spend
Commodity <------------------------------------------------------------------------------ > Service
Price Taker <------------------------------------------------------------------------------ > Price Maker
Asset Intense <------------------------------------------------------------------------------ > Labor Intense
Few Locations <------------------------------------------------------------------------------ > Many Locations

Source: Boston Strategies International, Inc.

**Extraction.** Extraction-oriented companies mine, handle, and/or transform primary raw materials. Product values and inventory values are low, while transportation costs are high as a percentage of delivered cost to the customer. They operate large-scale physical plants. They often use modes such as barge and rail. Sample industries include mining, agriculture, and energy. Price elasticity is high due to the commodity product, so they benefit significantly from transportation cost reductions.

**Process Manufacturing.** Process manufacturers are capital-intensive and operate few plants (maybe even one), and as a result transportation is a large share of the delivered price, so market reach is an important driver of profitability. Reliability and predictability reduce costs, so they seek more consistent transit times in order to help synchronize the flow of transportation and inventory with the pace of production. Process manufacturers are often found in the chemical, gas, steel, and processed food industries.

**Discrete manufacturing.** Discrete manufacturers make and stock inventory, so inventory is a significant cost driver and they have or use a large vehicle fleet to move it around. Therefore, infrastructure projects that allow them to reduce inventory, transportation costs, or fleet assets, will have a big impact. Discrete manufacturers are the most common type of manufacturer.

**Design-to-Order Manufacturing.** Design-to-order manufacturers do not ship product until it has been ordered, and usually ship directly to customers. They are usually engineering-intensive, hold low inventory, and have few vehicles. They use transportation benefits to extend market reach of capital-intensive physical plants. Design-to-Order Manufacturers can be found in a wide range of industries including aircraft, construction, and defense.

**Distribution.** Distributors buy finished product, add value to it, and resell it in a transformed state. Even their "raw material" inventory is high-value, so the ability to move product quickly and reliably is their core competence. Therefore, any combination of transportation benefits will allow them to create supply chain advantages, and pure distributors may be the most affected by improvements in transportation infrastructure of any other Supply Chain Type™. Distributors can be found in almost every industry, including industrial, food, automotive, and apparel.

**Reselling.** Resellers buy finished product and resell it in its identical state. Resellers include retailers, e-retailers, and direct mail advertisers. They spend relatively large amounts on transportation, largely because their retail outlets and/or their customers are so dispersed. They are responsible for inventory and have close collaboration with their consumer packaged goods suppliers. Resellers occur in many industries, including apparel, electronics, grocery, and restaurants.

If data is unavailable to estimate the number of firms of each of these types, a rough correspondence of the Supply Chain Types™ to NAICS Codes can be used (see Table A.2).

### Table A.2 Approximate Matching of Shipper Type to Selected NAICS Codes

| Code | Description | Extraction | Continuous Flow Mfg. | Make-to-Stock Mfg. | Design-to-Order Mfg. | Distribution | Retailing |
|---|---|---|---|---|---|---|---|
| 111 | Agricultural Products | 100% | | | | | |
| 112 | Dairy | 50% | 50% | | | | |
| 113 | Timber | 90% | 10% | | | | |
| 114 | Fishing | 80% | 10% | 10% | | | |
| 115 | Live Animals | 80% | | 20% | | | |
| 211 | Oil & Gas | 50% | 50% | | | | |
| 212 | Coal & Lignite | 90% | 10% | | | | |
| 213 | Crude Petroleum Products | 20% | 80% | | | | |
| 221 | Electric Power | 30% | 60% | | | 10% | |
| 234 | Construction Services | | | | 100% | | |
| 235 | Construction - Subcontracted Services | | | | 100% | | |
| 311 | Vegetables | 90% | | 10% | | | |
| 312 | Beverages | | 100% | | | | |
| 313 | Yarns | | 80% | 20% | | | |
| 314 | White Goods | | | 100% | | | |
| 315 | Apparel | | | 100% | | | |
| 316 | Leather & Furs | | | 100% | | | |
| 321 | Lumber & Wood | | | 100% | | | |
| 322 | Pulp And Paper | | 90% | 10% | | | |
| 323 | Bindings | | | 100% | | | |
| 324 | Refined Petroleum Products | | 70% | | | 30% | |
| 325 | Flammable Chemicals | | 90% | 10% | | | |
| 326 | Rubber & Plastic | | 50% | 40% | 10% | | |
| 327 | Household Goods | | | 100% | | | |
| 331 | Steel Products | | 50% | 30% | 20% | | |
| 332 | Forgings | | | 50% | 50% | | |
| 333 | Farm & Industrial Equipment | | | 80% | 20% | | |
| 334 | Computers & PDAs | | | 100% | | | |
| 335 | Lighting & Electrical | | | 100% | | | |
| 336 | Automobiles | | | 100% | | | |
| 337 | Wholesale Furniture | | | 80% | 20% | | |
| 339 | Instruments | | | 80% | 20% | | |
| 421 | Wholesale Durable Goods | | | 100% | | | |
| 422 | Wholesale Consumer Products | | | 100% | | | |
| 441 | Vehicle Dealers | | | | | 100% | |
| 442 | Retail Furniture | | | | | | 100% |
| 443 | Retail Appliances | | | | | | 100% |
| 444 | Retail Electronics | | | | | | 100% |
| 445 | Retail Food | | | | | | 100% |
| 446 | Retail Health & Beauty Aids | | | | | | 100% |
| 447 | Retail Health & Beauty Aids | | | | | | 100% |
| 448 | Retail Apparel | | | | | | 100% |
| 451 | Retail Leisure Supplies | | | | | | 100% |
| 452 | Retail Merchandising | | | | | | 100% |
| 454 | Direct Mail Services | | | | | 100% | |
| 483 | Waterborne Transportation | | | | | 100% | |
| 484 | Truck Transportation | | | | | 100% | |
| 485 | Public Transit Services | | | | | 100% | |
| 486 | Retail Natural Gas | | | | | 100% | |
| 488 | Aviation Services | | | | | 100% | |
| 492 | Air Freight Transportation Services | | | | | 100% | |
| 493 | Third Party Logistics Services | | | | | 100% | |
| 532 | Automobile Rental & Leasing Services | | | | | 100% | |
| 562 | Waste Management Services | | | | | 100% | |

Source: Boston Strategies International, Inc.

Note: Chart is indicative only and intended for use across broad sectors of the economy; data should be refined for application within individual industries. Shading indicates medium potential for category overlap.

## Determining the Transportation Cost of the Affected Population

Since supply chain benefits are estimated as a percent of transportation cost, the baseline transportation cost of each affected industry (as classified by NAICS and translated into Supply Chain Types™) must be gathered. The key data to take into the next step of the analysis for each Supply Chain Type™ consists of the number of companies (or employees), their transportation cost, and direct transportation cost savings benefit.

## Determining the Project's Impact on Transportation Costs

To assess the impact of a given project on company's supply chains, each of the benefits identified in this report is quantified using the global benefit ranges provided in Figure A.5 and the coefficients related to that Supply Chain Type™.

The benefits accrue in two categories: 1) benefits resulting from a reduction in transportation costs; and 2) benefits resulting from improved reliability.

- A **reduction in transportation cost** brings 1) greater supply network reach, 2) a reduction in the number of plants to serve the same market, and 3) a reduction in inventory from the use of smaller shipment sizes for the same price.
- **Improved reliability** brings: 4) a reduction in inventory and warehouses, as well as 5) a reduction in fleet assets

The next section describes the basic logic and key variables needed to compute simple, high-level valuations of each of these six unique supply chain benefits. *Note that these are "top-down" approaches based on averages across survey data.*

### Greater Supply Network Reach

From Figure A.5, we know that the degree to which lower transportation costs allow a firm to access lower-cost suppliers equates to 1.5 percent of transportation cost. For a general mix of industries, we can apply this to the average amount of sales that comes from outside suppliers (52 percent). However, the impact on companies of various Supply Chain Types™ depends on the significance of externally purchased materials in their cost structures. Table A.3 shows the relative difference in external spending between companies in each Supply Chain Type™.

**Table A.3 Externally Purchased Materials by Supply Chain Type™**

| Supply Chain Type | Externally Purchased Materials % of Operating Cost | Index Value |
|---|---|---|
| Extraction | 40% | 0.76 |
| Process manufacturing | 45% | 0.86 |
| Discrete manufacturing | 49% | 0.93 |
| Design-to-Order manufacturing | 49% | 0.93 |
| Distribution | 55% | 1.06 |
| Reselling | 77% | 1.46 |

Source: Boston Strategies International, Inc.

For example, for a Process Manufacturing company the impact of a 10 percent transportation cost reduction could be calculated by multiplying the average cost savings (1.5 percent), by the relative amount of Externally Purchased Materials for Process Manufacturing companies, (0.86), to arrive at a savings that equates to 1.3 percent of transportation cost.

**Reduction in Plant Assets.** The degree to which a company will be able to reduce the number of plants that it operates depends on: a) the amount of fixed assets it owns; and b) the degree to which a reduction in transportation costs allows it to reduce them. The asset intensity of companies can be estimated by the ratio of Depreciation to Operating Costs, as represented by Sales minus Operating Income. Depreciation/Sales is a standard benchmark that can be obtained and modified by the operating ratio to arrive at Depreciation/Operating Costs. Table A.4 shows the asset intensity of companies by Supply Chain Type™.

**Table A.4 Fixed Asset Intensity by Supply Chain Type™**

| Supply Chain Type | Fixed Asset Intensity (Depreciation % of Operating Cost) | Index Value |
|---|---|---|
| Extraction | 9.1% | 1.54 |
| Process manufacturing | 5.5% | 0.93 |
| Discrete manufacturing | 5.0% | 0.84 |
| Design-to-Order manufacturing | 4.3% | 0.73 |
| Distribution | 8.2% | 1.39 |
| Reselling | 3.3% | 0.56 |

Source: Boston Strategies International, Inc.

To demonstrate the supply chain benefit calculation, assume an Extraction business with an asset intensity index of 1.54, and a savings from extended market reach that equated to 4 percent of transportation cost. The potential reduction from reduced transportation cost from plant consolidation would equate to 6.2 percent of transportation costs (1.54 * 4%).

### Less Inventory Resulting from Smaller Shipment Sizes

The extent to which companies will reduce inventory by shifting to smaller shipment sizes depends on: a) the amount of inventory they keep on-hand; and b) the extent to which shifting to smaller shipment sizes will help them reduce it. Inventory on-hand is tracked and measured in numerous ways and published in a variety of periodicals and business almanacs. Table A.5 shows the inventory cost expressed as a percent of operating cost.

**Table A.5 Value of Inventory by Supply Chain Type™**

| Supply Chain Type | Cost of Inventory % of Operating Cost | Index Value |
|---|---|---|
| Extraction | 2.0% | 0.82 |
| Process manufacturing | 2.3% | 0.95 |
| Discrete manufacturing | 2.7% | 1.11 |
| Design-to-Order manufacturing | 2.6% | 1.09 |
| Distribution | 2.5% | 1.03 |
| Reselling | 2.4% | 1.00 |

Source: Boston Strategies International, Inc.

Using the data above for a Distribution business with an index value of 1.03, and applying the leverage factor of 1.20 percent noted in Figure 10, the benefit would equate to 1.24 percent of transportation cost.

### Reduction in Inventory and Warehousing Costs from More Consistent Transit Times

The extent to which companies will reduce inventory due to more consistent transit times depends on: a) the amount of inventory they keep on-hand; and b) the extent to which more consistent transit times will allow them to reduce it. Therefore, assuming a Design-to-Order manufacturing company with an Inventory/Transportation Cost ratio of 1.09, and applying the average leverage factor of 1.1 percent, the benefit would equate to 1.2 percent of transportation cost.

### Reduction of Fleet Assets

Companies' ability to reduce fleet assets as a result of increased transit time reliability is a function of: a) fleet operating costs adjusted for the fleet size and demand peaking profile in inherent in different Supply Chain Types™; and b) the degree to which reliability allows them to eliminate vehicles by compressing turntimes. Table A.6 shows the private fleet intensity for each Supply Chain Type™.

For a Reseller with a relative fleet intensity of 1.0, and a savings from fleet rationalization of 0.3 percent, the potential reduction from reduced transportation cost from fleet rationalization would be 0.3 percent of operating costs (1.0 fleet intensity factor * 0.3 percent savings from reduced turntime).

**Table A.6 Private Fleet Expenses as a Percent of Operating Cost by Supply Chain Type™**

| Supply Chain Type | Own-Account Transportation as % of Operating Cost | Index Value |
|---|---|---|
| Extraction | 4.0% | 2.7 |
| Process manufacturing | 1.0% | 0.7 |
| Discrete manufacturing | 0.7% | 0.5 |
| Design-to-Order manufacturing | 0.8% | 0.5 |
| Distribution | 0.9% | 0.6 |
| Reselling | 1.5% | 1.0 |

Source: Boston Strategies International, Inc.

# APPENDIX B. CASE STUDIES

This appendix presents four case studies describing economic evaluations of proposed freight investment projects. It shows how each of the evaluations included some elements conforming to the five-step analysis process presented in this guide. It concludes with an assessment of lessons learned and factors that make various studies differ in their treatment of project benefits and costs. Together, these case studies are intended to complement the in-depth example presented in Chapter 8. Of course, it is important to keep in mind that none of these studies were originally intended to meet the full guidelines in this document. However, they do show how there is a common thread of analysis steps underlying all economic impact evaluations for major freight projects.

## B.1 Summary Case: Inland Empire Rail Shuttle

### Step 1 – Classify Type of Project

The Inland Empire Rail Shuttle project represents a truck to rail modal diversion project intended to reduce highway congestion and associated costs. The goal of the rail shuttle is to divert some of these short haul (50 to 100 miles) truck trips off of California's congested freeways and onto the freight rail system, making greater use of the Alameda Corridor. A number of proposals to develop such a service have been evaluated by various parties. This case study is based on analyses conducted for the Alameda Corridor Transportation Authority looking at several early concepts. The analyses were intentionally conducted at a sketch planning level.

Three operational alternatives were analyzed for the rail shuttle between the Ports of Los Angeles and Long Beach and the Inland Empire: a 'long-haul piggy back' that would attach container cars bound for the Inland Empire to long-haul trains scheduled to travel along the route already; a 'dedicated shuttle service' that would assemble three trains from the on-dock facilities; and finally the 'commuter line service', which would also assemble dedicated trains at the docks but instead of running along freight lines would use mostly public lines currently used primarily for commuter trains.

### Step 2 – Define the Relevant Evaluation Issues to Focus On

Public sector interest in the rail shuttle project stems from several factors. As noted in various reports, approximately 35 percent of all U.S. waterborne container cargo is handled at the Ports of Los Angeles and Long Beach. As such, these ports represent a nationally significant freight transportation asset. Ensuring efficient operation and adequate landside access to these ports would appear to be in the national interest. The potential consequences to the nation of increasing landside congestion and associated disruptions of supply chains could result in higher cost goods to consumers and businesses even if container cargo is diverted to other ports. However, the costs to the national economy of landside congestion or cargo diversion at the ports have not been clearly demonstrated. Cargo diversion could also have significant local/regional economic effects. Finally, explosive growth at the Ports of Los Angeles and Long Beach has created a number of externalities within Southern California including contributions to local congestion on roadways, increased air and noise pollution, and safety impacts of increased truck traffic on the regional roadway system. At some level, the rail shuttle project is intended to address all of these issues by diverting truck traffic to rail.

The analysis also sought to examine how the rail shuttle could contribute to revenue generation for the Alameda Corridor Transportation Authority (ACTA) needed to service debt from the development of the Corridor. The rail shuttle would represent an opportunity to re-capture some of ACTA's revenue lost to increased trans-loading activity given the fee structure that ACTA had established.

The economic objectives of the rail shuttle proposal study on behalf of ACTA sought to:

- Estimate costs and revenues from a competitively priced service in order to determine if the project could be self-supporting. If a subsidy would be required, the analysis would estimate the magnitude of the subsidy. Capital costs and operating costs are also developed and compared to expected revenues. The rationale was that sources of funding to subsidize one time capital costs could be easier to identify than sources for ongoing operating subsidies.
- Determine if estimated public benefits exceed costs from a public perspective in order to justify the project.

## Step 3 – Select and Apply the Analysis Tools to Estimate Transportation Impacts

Net local public benefits would result from the subsequent reduction in truck trips that the rail shuttle would generate (and the associated savings per mile of reduced truck trips). Fewer truck trips means congestion relief and associated travel time benefits for the remaining highways users (auto and truck).

Two independent estimates were developed to forecast the potential market for shuttle service between the ports and the new intermodal rail terminal. The first extrapolated current activity levels at BNSF's San Bernardino intermodal yard; the second was based on the recently completed survey of distribution centers and warehouses in a four county region of Southern California. Both estimates generated similar values of between 1.2 to 1.3 million TEUs of imports traveling between the ports and the proposed intermodal yard.

The assessment of the market share that could be captured by the shuttle service was based on an analysis that used a competitive price for the service compared to the price of existing truck drayage services, and was supported through interviews with shipping companies. The report estimated that initially 20 percent of the market could be captured, with five percent growth per year up to a 40 percent cap on market share.

Based on this information, the study calculated the number of TEUs that would be captured by the shuttle service and converted that value into a corresponding number of truck trips that would be eliminated. The annual number of truck trips was multiplied by 60 miles (assumed average highway distance of the eliminated truck trips from the ports to the Inland Empire) to determine the VMT savings.

VMT savings were directly calculated in the analysis using the sketch planning method described above. The added value of reduced pavement deterioration, reduced air pollution, reduced congestion, reduced crashes, and reduced noise were also calculated as a function of the VMT savings.

## Step 4 – Select and Apply Analysis Tools to Estimate Economic Impacts

The quantitative economic impact analysis was focused on direct economic benefits of the rail shuttle operation for freight movement. The reduced truck vehicle miles traveled were converted into savings (due to diversion from truck to rail) using data from the FHWA's Highway Cost Allocation Study.[30] This report calculated cent per mile rates for various factors for five vehicle classes in both urban and rural settings. An average value was derived from 60,000- and 80,000-pound, five-axle combination trucks operating on a combination of rural and urban highways. Listed benefits included a reduction in air pollution (12 percent of the total value of public benefits), pavement wear (49 percent), congestion (32 percent), accidents (3 percent), and noise reduction (5 percent). The congestion benefit measured reductions in travel time delay for the remaining highway users.

Essentially, the Highway Cost Allocation Study calculates the marginal cost of an incremental mile of travel for different vehicle classes and rural versus urban highways. The loss of income from reduced fuel tax revenue was also factored into the analysis. The total net public benefits were estimated at $177 million over the 25-year life of the project, most of which are local/regional in nature.

[30] *Federal Highway Cost Allocation Study*, U.S. DOT, FHWA, May 2000.

Several non-monetized advantages associated with the implementation of a shuttle service were also noted, including:

- Improved sea terminal productivity;
- Reduced need for chasses at the port;
- Benefit to businesses of scheduled, reliable deliveries;
- Improved efficiency of handling rail-based flow of cargo versus truck-based; and
- Opportunity for cargo storage pens at the Inland Empire for shippers.

A financial pro-forma was also prepared to demonstrate the feasibility of the shuttle service over a 25-year period. The pro-forma incorporated the benefits and costs detailed, and calculated that the shuttle would have a positive net present value of operating income (operating revenues minus operating costs) of approximately $36 million at a 5.5 percent discount rate over the first 25 operating years, although profitability would not be achieved for the first decade of the project's life. The estimates of operating revenues were based on the price per container charged to users and included the ACTA use fee (for use of the Alameda Corridor). The net present value of ACTA fees collected was estimated at $184 million.

### Step 5 – Apply Relevant Decision Methods

The decision method used in this analysis was a benefit-cost analysis. The value of the net public benefits (derived from reduced truck VMT) was estimated to total $177 million over the life of the project, while the operating income was estimated at $36 million, for a total benefit of $213 million. When compared to the potential total capital costs of $190 million, a positive benefit-cost ratio was supported.

The study concluded that rail shuttle service between the ports and the Inland Empire distribution and warehousing complex was both operationally feasible and economically viable. The study noted that some level of financial support would be necessary in order for the service to be able to compete with the trucking industry, but that the anticipated reduction in congestion and emissions would justify this support.

## B.2 Summary Case: Chicago CREATE

### Step 1 – Classify Type of Project

The Chicago Region Environmental and Transportation Efficiency Project (CREATE) can be classified as achieving *operational improvement* with respect to freight rail, and *augmenting capacity* with respect to passenger rail (an explicit METRA objective). These improvements would be possible by removing bottlenecks, improving the fluidity over the system (i.e., fewer delays, better speeds, added reliability) and more prompt recovery of operations after bad weather or accidents.

CREATE would not per se represent a rationalization of the existing network since there will be little change in the network (apart from the elimination of the St. Charles Airline route). Instead CREATE's intention is focused on rail traffic along five corridors (Central, Western Avenue, East-West, Beltway, and a dedicated Passenger route). These five routes would be streamlined relative to their current operational characteristics to become "through-routes," grade separations would be achieved at 25 major street crossings, and six flyovers would be constructed at critical rail-to-rail intersections (typically passenger vs. freight rail conflicts). The effective separation of freight and passenger train movements at specific points in the network would add capacity to the Southwest and Heritage lines, allow better use of the LaSalle Street Station, and free-up capacity at the Union Station.

## Step 2 – Define the Relevant Evaluation Issues to Focus On

The public benefits analysis of the CREATE proposal attempted to evaluate three of the four issues defined in Chapter 4 – national growth/productivity implications, savings to rail operators, and the allocation of costs, benefits and the mix of beneficiaries. The latter was important since for the first time ever, *six* private railroad entities[31] began a joint process with the city of Chicago (Mayor's Office, CDOT, METRA, AMTRAK) and the state of Illinois (IL DOT) to devise (and eventually cost share) improvements to the current railroad system that would address both freight and passenger rail movements, reduce conflicts between rail and auto/truck movements at crossings and help mitigate Chicago's growing surface congestion.

Operational benefits for the six railroad operators would follow from the investment to improve rail network efficiencies. The public-benefits focus was on the local rail serving market of Chicago-Kenosha-Gary CMSA and on the nation as well. These benefits, which were monetized and expressed in net present value over the period 2003 to 2042, included:

- Inventory reduction savings (National assessment only);
- Highway investment averted and congestion mitigation on future highway passenger traffic growth;
- Rail commuter's time savings/ Motorists time savings at crossings (Regional assessment);
- Savings tied to accident reduction at crossings (Regional assessment);
- Savings tied to accident reduction on less congested highways (Regional assessment);
- Project Construction Economic Stimulus (Regional assessment); and

[31] CSX, UP, Norfolk Southern, BNSF, Canadian Pacific, and Canadian National.

- Value of emission reductions due to reduced train & motor vehicle idling (Regional assessment).

Other benefits were noted, but not measured since they were considered secondary benefits. They included the value of improved rail freight service to Chicago-area businesses, better emergency response times along 911 routes for the community, redevelopment of lakefront by eliminating the St. Charles Airline route, reducing rubber tire interchanges (drayage), and energy conservation.

## Step 3 – Select and Apply the Analysis Tools to Estimate Transportation Impacts

The public-benefits analysis relied upon transportation modeling resources of ILDOT, the Chicago Area Transportation Study (CATS), and some additional methods. Accident reductions from improved crossings as well as less congested highways (achieved by modal shift into passenger rail) were drawn from these agency resources. For example, the safety benefits associated with the grade crossing separations were estimated based on historical accident rates at the 25 crossings, with an assumption about traffic growth at the crossings. Additional safety benefits were associated with the investment as it has the potential to spur added passenger rail traffic growth (particularly attributable to the rail flyover improvements). By estimating the highway traffic that would have been generated in lieu of added growth in commuter rail use, incremental accidents were identified.

The rail operators' study relied on the Berkeley Simulation model to estimate rail network performance changes for both freight and passenger rail activity. This modeling revealed network performance changes under different allocations of a specific mix and volume of rail traffic over the network. Railroad operators then determined the associated scheduling, costs of operations as well as rate structures based on the simulation results.

## Step 4 – Select and Apply Analysis Tools to Estimate Economic Impacts

For CREATE's various economic impact potentials identified in Step 2 above, some formal analysis tools were applied and in some instances less formal methods were used. The direct economic value of inventory reduction savings were calculated by multiplying the time saved on freight movement by value of delay, all at the commodity-specific level. The value of delay was based on the direct cost savings that would result from not holding the shipments in inventory longer as a result of the trip being faster. The (undoubtedly more significant) benefits that would be derived from increased reliability of shipments were not possible to address. The study used the value of the lading, a cost of capital, and the time-savings, hence the resulting NPV for this impact was small. AAR believes this is a conservative estimate for the Nation.

The value of averted highway construction/repair was derived using slightly different sources of information for the local and national public-benefits analyses. The national estimate was derived from the FHWA Highway Economic Requirement System (HERS) model and from an analysis tied to AASHTO's *Freight-Rail Bottom Line Report* (2003). For the local estimate of averted highway spending, METRA provided forecasts of passenger growth (inclusive of CREATE's operational improvements) along the Southwest and Heritage lines, CATS and ILDOT the forecasts of car pooling growth and the average decline in trip length – all combined to yield a decline in vehicle-miles-traveled (VMT). The HERS model was then able to assign the investment savings to the local highway system based on reduced VMT.

The value of emission reductions are estimated using reductions in rail-fleet idling time as well as the auto/truck delay improvements at the improved (grade separated) crossings as well the 163 other crossings. The modeling results indicated that the railcar time saved and current emission standards from EPA for locomotive emissions were used with data from CATS' recent CMAQ analysis for approved $NO_x$ projects as the basis for monetizing the pollutant tons averted). Auto/truck emission reductions were identified in part from the Berkeley Simulation model results of improved rail activity at the crossing points, and from the CATS data for existing as well as future highway traffic as it was assumed to be distributed over the road network. Dollar valuations were derived from the same source as the rail-related emission reductions. Finally, the economic impact resulting from construction of CREATE's project components was also estimated using a regional input-output model.

## Step 5 – Apply Relevant Decision Methods

The study of public-benefits began once the CREATE proposal was finalized among the rail operators based on the simulation results from their private study. Due to the confidential nature of that study, the explicit decision methods used for identifying the investment package are not known to the public. At minimum the operational improvements would be worth $0.2 billion of rail industry funding towards the overall cost of CREATE.

Public-entity funding will involve METRA, CDOT, ILDOT, and Federal funding. Organizations such as METRA that have already agreed to contribute may have done so on the basis of considerations such as the added fare revenue tied to induced growth in commuter rail ridership. That information was produced by the simulation forecasting process.

# B.3 Summary Case: Vancouver Gateway's MCTS Project

## Step 1 – Classify Type of Project

Vancouver, BC serves as one of North America's premier sea and air gateways for Asia trade, as well as for rail and highway freight shipments across the U.S./Canada border. However, growth of these multimodal port facilities has been putting increasing pressure on the region's ground transportation system. The growth of road and rail traffic has been particularly strong for commercial movements, which serve freight cargo moving to and from airport, marine ports, industrial parks, and international border crossing facilities. Projected road and rail demand indicate that capacity will soon be exhausted for both elements of the transportation system. In the meantime, increasing traffic congestion is affecting not only freight flows, but also residents who commute to work or travel to the central city for personal business.

The Greater Vancouver Gateway Council, a private-public partnership, defined the concept of a Major Commercial Transportation System (MCTS) as a multimodal system with new infrastructure investments to maintain functional linkages between Gateway facilities, industrial areas and the major trade routes by sea, air, road, and rail. A series of 18 major new investments, comprising major highway upgrades as well as new or improved rail links and river crossings (by both rail and road), were identified as necessary to maintain the movement of goods and to reducing increasingly high levels of traffic congestion. Improvements to an additional 34 existing roadway segments, rail facilities, and rail/road crossings were also identified. The cost of completing all of these projects is estimated at $6 billion.

The MCTS encompasses all three facility location types discussed in Chapter 3 (local entry/access point, regional corridor, terminal facility) and the project's goal is operational improvements as well as capacity expansion.

## Step 2 – Define the Relevant Evaluation Issues to Focus On

Local issues include traffic delay for commuters and other peak period travelers. Regional issues include the ability for continued growth in the metropolitan area and its marine, rail, and trucking industries and allied industries. These issues correspond to international trade growth and local/regional income and economic development areas discussed in Chapter 4.

## Step 3 – Select and Apply the Analysis Tools to Estimate Transportation Impacts

The analysis process brought together a team of transportation engineers and economic development consultants to apply a series of sophisticated models:

- Multimodal cargo forecasting – The economic consultant worked together with regional planning and provincial economists to derive cargo traffic forecasts by mode, based on provincial economic forecasts, regional demographic forecasts, cargo value/ton relationships and international trade responses to international changes in exchange rates and prices. The forecasting system was used to identify the extent of traffic growth associated with marine ports, the airport, rail yards and border crossings.
- Traffic simulation model – The EMME/2 transportation planning model system was calibrated for the Vancouver region by TransLinks – the regional transportation agency. A special version included highly detailed freight analysis with specific detail on flows to/from marine port facilities. This was used to estimate peak and daily traffic flows, identify locations of congestion, and truck and car vehicle-kilometres and vehicle-hours of delay.
- Railroad facility supply/demand forecasting system – The engineering firm developed a model of railroad supply capacity vs. demand, for each of the region's rail yards and railroad bridges. The model estimated growth of train carloads, train length and schedule spacing constraints, and implications for stunting rail capacity without investment to overcome expected future rail bottlenecks at river crossings.

## Step 4 – Select and Apply Analysis Tools to Estimate Economic Impacts

A *four-province* economic impact study was funded by the Canadian Federal Department of Western Economic Diversification, in cooperation with Transport Canada, because all four of Canada's western provinces are economically dependent on international trade flowing through the Vancouver region.

The study used an early version of the economic analysis system that is now referred to as TREDIS (Transportation Economic Development Impact System) to evaluate regional economic impacts. This system consisted of a) Rail Capacity Module – calculation of economic growth loss associated with failure to increase rail system capacity to meet forecast cargo growth needs, b) Highway/Cost Response Module – calculation of business cost increase and shift of business growth away from Western Canada due to higher cost of truck and rail through congested routes to international gateways, c) Input/Output Module – a series of four provincial input/output models were used to allocate direct effects on affected business to downstream impacts on the western Canadian economy, and d) Net Benefit Module – a series of adjustment factors that allowed for business relocation and workforce adjustment to calculate net impacts on GDP, jobs and income in the region.

## Step 5 – Apply Relevant Decision Methods

Performance metrics for the various components of the Vancouver Gateway's multimodal transportation infrastructure were required in order to assess whether the proposed investment for the MCTS would address growing congestion – affecting both international trade growth and local/regionally oriented economic activity as well. The analysis provided the following quantitative results:

- *Highway System Impact* – Reduction in road system delay associated with excess VKT (VMT) and VHT for commercial vehicle operations, commuting and overall highway network efficiency in the region;
- *Railroad System Impact* – Improvement in ability of the system to maintain capacity to meet projected demand (trains, carloads and value of goods) using the rail system;
- *Marine Port Impact* – Ability to avoid losses of gateway port economic activity (jobs and income) that would otherwise occur over time as a consequence of rail and highway capacity and throughput limitation; and
- *Economic Health* – Ability of the Vancouver region, BC province and Western Canada to maintain its economic vitality and importance by avoiding loss of business activity (as well as jobs and income) that would otherwise occur due to higher business costs and gateway transport system capacity limitations.

The study concluded that the package of highway, rail, and public transit projects had a benefit significantly greater than the cost, whether measured in terms of travel benefit, economic growth or societal benefit. Based on those findings, the project was endorsed by the Vancouver Gateway Council and discussion went forward between Federal, provincial and regional transportation departments for prioritizing and funding the listed projects. At this time, some of the recommended projects have been approved for implementation.

# B.4 Summary Case: NY Cross Harbor Freight Rail Tunnel

### Step 1 – Classify Type of Project

The Cross Harbor Goods Movement EIS for the New York City Economic Development Corporation is a project to assess the impacts of a new freight rail tunnel from New Jersey (or Staten Island) to Brooklyn, along with other rail line improvements and an intermodal rail yard in Queens. So, the mode directly affected is freight rail transportation, with completely new infrastructure (the tunnel and intermodal yard) and enhanced existing infrastructure (the current rail lines in Brooklyn and Queens).

## Step 2 – Define the Relevant Evaluation Issues to Focus On

One of the primary goals of the project is to divert freight from trucks to rail, thereby reducing the number of trucks on the metropolitan New York City highways and in particular, reducing truck traffic on the bridges.

Local impacts include enhanced freight rail service to East of the Hudson areas such as all of Long Island, and a new intermodal yard in Queens and projected increases in warehousing/distribution activity. Regional impacts are expected to include shifts in mode from truck to rail for various commodity movements to/from East of Hudson locations, reductions in highway congestion and truck traffic in greater New York and New Jersey, and reduced freight transportation costs for regional businesses and spillover economic benefits. National impacts are also expected since various long-distance goods movement trips that currently use trucks may switch to rail, thereby reducing truck volumes on national highways. In addition, freight moves that have origins and destinations outside of the metropolitan New York City area but will benefit based on the new rail tunnel are expected to experience reduced shipping costs.

## Step 3 – Select and Apply the Analysis Tools to Estimate Transportation Impacts

Transportation models and their associated data included:

- Shipper choice model – Customized model developed through a series of carefully constructed surveys of businesses in the local area to understand the conditions under which freight could switch from trucks to rail. The model was calibrated using Reebie Associates' TRANSEARCH commodity flow data.
- Highway network model – Travel demand model for the New York City metropolitan area (including parts of New Jersey and Connecticut) maintained by the New York Metropolitan Transportation Council, including data for trucks and auto trips on speed, trip patterns, volumes, etc.
- User benefits model from STEAM – Adapted user benefits model from the Surface Transportation Efficiency Analysis Model (STEAM), including values of time, and parameters for operating costs, emissions, and accident rates.

## Step 4 – Select and Apply Analysis Tools to Estimate Economic Impacts

Three types of direct economic benefits based on travel efficiency were estimated:

1. New rail trips using the tunnel would lessen the number of truck trips. (The dollar-based estimate of the cost savings derived by diverting a truck trip to rail takes into account travel time and reliability differences.)
2. Existing rail trips that benefit from using the tunnel. The monetized benefits to shippers would accrue from reduced travel time and cost and improved reliability for trips using the tunnel as compared to the Selkirk Bridge (close to Albany).
3. Business-oriented highway trips (truck and business-auto) would benefit from reduced highway congestion as a result of reduced truck trips. The dollar-based estimate for business-oriented highway trips benefiting from accident cost savings, vehicle operating cost savings, and travel time savings due to a reduction in the number of trucks on the highway system.

Economic impact models included:

- Business cost savings model – A customized spreadsheet model to allocate benefits to highway and rail users to industry sectors for input into a regional economic impact model.
- Land use business attraction/retention model – A customized spreadsheet model was developed to estimate the potential for business attraction/retention due to greatly enhanced freight rail service and a new intermodal yard. Data included land use data by parcel (size, zoning, building square feet), real estate data from a commercial vendor regarding vacant land and utilization rates at existing industrial sites, and conversion factors to estimate employment potential based on square feet.
- Regional economic impact model – A 14 region economic simulation and forecasting model (REMI Policy Insight) was used to estimate full economic impacts to the region and nation.

## Step 5 – Apply Relevant Decision Methods

The economic analysis metrics used in the decision-making process included: 1) a benefit-cost analysis spreadsheet model to track benefits and costs, discount to present value, and calculate benefit-cost ratios; and 2) economic benefits in terms of gross regional product (GRP), employment, and personal income.

# B.5 Lessons Learned from the Case Studies

**Common Features.** Each example reflects an attempt to answer – through some type of analysis – an explicit study objective(s) pertaining to the value of a proposed investment in some component of the freight transportation system. The path each analysis evolved along is clearly a function of a) how many evaluation issues were articulated by the key stakeholder funding the study; b) the analytical resources (budget/modeling tools/skills) available to develop the analysis; c) the execution of the analysis; and d) the ultimate decision criteria used to interpret the economic impact results from these projects.

Three common findings are that:

1. Many sponsors of freight economic studies do not possess the resources to obtain, develop, and use the full range of modeling tools described in this guide. Some of the studies intentionally relied upon sketch-planning methodologies that used rules of thumb. Some of them did not include full economic modeling of regional and macroeconomic impacts. Regional economic simulation models can be expensive relative to overall analysis budgets.
2. Many of the studies have focused on state or regional impacts and have not included a national perspective for viewing benefits. That can be appropriate for local and state audiences, but it limits the capture of comprehensive benefits of interest to U.S. DOT.
3. Benefit concepts can vary greatly from study to study and often do not include key information that is most useful to U.S. DOT decision-makers. For example, some studies focus more on private sector benefits rather than broader public benefits, and some studies only calculate direct first order transportation effects, but ignore second order logistics effects and economic gains to industries.

Overall, these case studies confirm that economic impact is an important consideration when evaluating major freight transportation projects. Differences among these case studies also emphasize the value of guidelines, as presented in this document, to better standardize methods and presentation of findings for future freight economic impact studies. This latter point is particularly important for projects in which Federal funding or other forms of Federal participation are being considered.

CAMBRIDGE SYSTEMATICS

Economic Development RESEARCH GROUP

Boston Logistics Group