Identifying and Using Low-Cost and Quickly Implementable Ways to Address Freight-System Mobility Constraints

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NCFRP REPORT 7

Identifying and Using Low-Cost and Quickly Implementable Ways to Address Freight-System Mobility Constraints

Battelle
Columbus, OH

IN ASSOCIATION WITH

Jeffrey Short, Todd Trego, and Dan Murray
AMERICAN TRANSPORTATION RESEARCH INSTITUTE
Arlington, VA

Joan Yim and Timothy Neuman
CH2M HILL
Bellevue, WA

Gordon Proctor
GORDON PROCTOR AND ASSOCIATES
Dublin, OH

Robert Gallamore
THE GALLAMORE GROUP
Rehoboth Beach, DE

Shobna Varma
STARISIS CORPORATION
Lewis Center, OH

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

America's freight transportation system makes critical contributions to the nation's economy, security, and quality of life. The freight transportation system in the United States is a complex, decentralized, and dynamic network of private and public entities, involving all modes of transportation—trucking, rail, waterways, air, and pipelines. In recent years, the demand for freight transportation service has been increasing fueled by growth in international trade; however, bottlenecks or congestion points in the system are exposing the inadequacies of current infrastructure and operations to meet the growing demand for freight. Strategic operational and investment decisions by governments at all levels will be necessary to maintain freight system performance, and will in turn require sound technical guidance based on research.

The National Cooperative Freight Research Program (NCFRP) is a cooperative research program sponsored by the Research and Innovative Technology Administration (RITA) under Grant No. DTOS59-06-G-00039 and administered by the Transportation Research Board (TRB). The program was authorized in 2005 with the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). On September 6, 2006, a contract to begin work was executed between RITA and The National Academies. The NCFRP will carry out applied research on problems facing the freight industry that are not being adequately addressed by existing research programs.

Program guidance is provided by an Oversight Committee comprised of a representative cross section of freight stakeholders appointed by the National Research Council of The National Academies. The NCFRP Oversight Committee meets annually to formulate the research program by identifying the highest priority projects and defining funding levels and expected products. Research problem statements recommending research needs for consideration by the Oversight Committee are solicited annually, but may be submitted to TRB at any time. Each selected project is assigned to a panel, appointed by TRB, which provides technical guidance and counsel throughout the life of the project. Heavy emphasis is placed on including members representing the intended users of the research products.

The NCFRP will produce a series of research reports and other products such as guidebooks for practitioners. Primary emphasis will be placed on disseminating NCFRP results to the intended end-users of the research: freight shippers and carriers, service providers, suppliers, and public officials.

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Dr. Edward Fekpe, a Research Leader with Battelle, was the principal investigator for the project and the lead author of this report. Other contributing authors are Dr. Robert Gallamore of The Gallamore Group, Jeffrey Short and Todd Trego of ATRI, Joan Yim and Timothy Neuman of CH2M HILL, Gordon Proctor of Gordon Proctor and Associates, and Shobna Varma of StarIsis Corporation. Other project team members that contributed to the development of this report are Mohammed Majed and Garnell Sowell of Battelle, Dan Murray of ATRI, and Brian Painley of CH2M HILL.

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FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

NCFRP Report 7: Identifying and Using Low-Cost and Quickly Implementable Ways to Address Freight-System Mobility Constraints develops standardized descriptions of the dimensions of the freight transportation system, defines freight mobility constraints in a multimodal context, provides criteria for low-cost and quickly implementable improvements to address the constraints, and provides a software tool to help decision makers in evaluating constraints and selecting appropriate improvements. The report will enable both the public and private sectors to benefit from operational improvements, organizational changes, and other low-cost ways to address freight-system mobility constraints.

The nation's freight infrastructure is well established and mature but overburdened. Increasing congestion inflicts costs on shippers, consumers, and the environment. Evolving technologies, growing demand, changing business practices, shifting patterns of commerce, and government policies designed to address environmental and other public concerns have impacts, sometimes unintended, on freight system performance. Because expansions to the freight transportation system are often complicated and expensive, both private-sector firms and public policymakers often try to find operational improvements, organizational changes, or other low-cost and quickly implementable ways to address mobility constraints.

Under NCFRP Project 4, Battelle was asked to (1) develop a standardized description of the dimensions of the freight system by mode; (2) analyze explicitly the business practices and institutional factors that influence freight-system decision makers and stakeholders as they respond to freight-system mobility constraints and regulatory and other public policy initiatives; (3) develop a methodology that both the public and private sectors can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and public policy actions that can enhance freight mobility by addressing system constraints; and (4) apply that methodology in a generic way to create a catalog of actions that may be most useful in addressing the nation's freight-system mobility constraints.

To accomplish the project objectives, the research team (1) developed definitions of freight mobility constraint; (2) developed criteria for low-cost and quickly implementable improvement by mode; (3) characterized the improvements by physical improvements, operational improvements, and regulatory improvements; and (4) developed a computer-based application analysis tool for users to identify constraints based on selectable criteria and then to review possible improvements based on documentation of the experiences of departments of transportation and others.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

SUMMARY

Identifying and Using Low-Cost and Quickly Implementable Strategies to Address Freight-System Mobility Constraints

Increasing freight demand and capacity constraints present several challenges to the management and operation of the freight transportation system. Recent studies and statistics document the inadequate capacity and the resulting increasingly costly congestion—not only on the nation's highways but also in metropolitan areas, at water ports, railroads, airports, and intermodal facilities. The ability to increase freight transportation capacity to meet demand is constrained by geographic barriers, population density, and urban land use development patterns. The consequences of this increased freight demand and increased density include increased congestion, travel delay, emissions, and commercial operational costs, among others.

Freight mobility is constrained not only by physical infrastructure inadequacies but also by operational, regulatory, policy, technological, and financial limitations. With inadequate revenue to invest in major system capacity expansion and new system technology, there is increased interest in addressing freight mobility constraints through innovative operational strategies, performance-improving regulatory and policy changes, and low-cost capital improvements.

This project developed standardized descriptions of the dimensions of the freight transportation system (highway, rail, and deepwater ports and inland waterways), defined freight mobility constraints in a multimodal context, developed criteria for low-cost and quickly implementable improvements to address freight mobility constraints, and developed a software application tool to help decision makers in evaluating freight mobility constraints and selecting appropriate improvements.

Definition of Freight Mobility Constraint

While there is no common or single definition of freight mobility constraint, the definitions share common themes. Based on these common themes, a freight mobility constraint can be defined as

> a physical or infrastructure deficiency, regulatory requirement (Federal, state, or local), or operational action that impedes or restricts the free flow of freight either at the network level or at a specific location.

Mobility constraints increase costs, contribute to system inefficiencies, and delay on-time freight delivery. The three main types of constraints are:

- *Physical Constraints*—any geometric or infrastructure conditions that constrain freight operators from operating at free-flow speeds, and within legally required parameters. Examples include inadequate capacity within the transportation system (e.g., mainlines, interchanges, rail sidings, port terminals) and geometric restrictions or limitations affecting safe and efficient mobility.

- *Operational Constraints*—practices, processes, events, or occurrences that constrain optimal throughput and efficient operating conditions. Examples include poor signal phasing, inefficient port terminal gate processes, technological limitations, and outdated signaling systems.
- *Regulatory Constraints*—Federal, state, or local regulatory requirements that have unintended consequences that restrict the flow of freight through the system. Examples include safety and security requirements, truck restrictions, air quality restrictions, and labor contractual limitations.

Criteria for Low-Cost and Quickly Implementable Improvement

Although many innovative, low-cost efforts are being implemented by public and private stakeholders, there are no widely accepted criteria to define what constitutes a low-cost improvement directed to enhance freight mobility. A "low-cost" and "quickly implementable" improvement to address freight mobility constraints may be defined as:

> an action that modifies existing geometry and/or operational features of the freight transportation infrastructure system and that can be implemented within a short period without extended disruption to traffic flow. Such an improvement may be physical, operational, or regulatory, as long as it enables greater and more efficient throughput from existing facilities. These actions may be spot (or location-specific) improvements or may be limited to short sections of the physical infrastructure. Likewise, they may be specific to a given supply chain process point, regulation, or mode; they may also affect multiple modes of freight movement. Furthermore, low-cost improvements do not involve massive reconstruction of infrastructure that usually takes many years to complete.

Table ES-1 summarizes the modal characteristics of low-cost improvements that can be implemented quickly.

Characterization of Improvements

The ideal improvement action, which may be physical, operational, or regulatory, does not always correspond directly with the type of mobility constraint. For instance, operational improvements can be used to address physical constraints and vice versa. Similarly,

Table ES-1. Key features of low-cost and quickly implementable improvements.

Mode	Characteristics of Low-Cost Actions	Time to Implement
Highways	• Less than $1 million • Spot or location-specific improvements • No environmental clearances necessary • No right-of-way acquisition • No special programming required • Implementation at district or lowest operation unit level (limited direct HQ oversight)	Less than 1 year
Railroads	• Class I railroad – $1 million to $10 million	Less than 2 years
	• Regional railroad – less than $2 million	Less than 1 year
	• Short-line railroad – less than $500,000	Less than 6 months
Deepwater Ports & Inland Waterways	• Less than $1 million • Essentially incentive-based programs to influence demand and changes in operational practices, and technology deployments • Physical improvements coordinated with highway and rail projects within and outside the port terminals at links serving ports – location-specific actions • Uniqueness of each port acknowledged	Less than 2 years

regulatory and policy actions can be implemented to mitigate operational and physical constraints. Policy-type improvements are considered as regulatory, while economic-based actions that affect price and market-based solutions are classified as operational improvements. While physical improvements are quite distinct, certain types of improvements could fit either regulatory or operational categories. The following are generic definitions of the primary types of improvements:

- *Physical Improvements*—typically involve construction activities to improve geometry or to add capacity. Examples include widening of lanes, extensions to rail sidings to allow longer trains, and addition of space to increase terminal capacity.
- *Operational Improvements*—activities directed at reducing occurrences of conflicts and delays to traffic and processes and may include implementation of technology and changes in operational schedules, practices, and sequences. Examples include upgrades to signal phasing at intersections, congestion pricing to control demand, use of economic-incentive strategies to control demand, and use of centralized train control systems.
- *Regulatory Improvements*—institution of or changes to regulations, policies, and actions that improve freight mobility on the transportation system. This includes labor agreements, stakeholder partnerships directed at improving cooperation among modes, and other public and private stakeholder partnerships for the primary goal of improving freight mobility. Examples include revisions of regulations governing the operating hours of freight vehicles especially in central business districts during peak hours, changes in land use and zoning laws to provide more parking for freight vehicles, and land border crossing requirements and controls.

Analysis Tool

A major output of this research is a methodology that decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and regulatory or public policy actions. The methodology is embodied in a computer-based application tool (available on the CD-ROM bound into this report) where users can identify constraints based on selectable criteria and then review possible improvements based on documentation of the past experiences of departments of transportation and others. Links to resources for more detailed information supporting each implemented project are also provided. Figure ES-1 shows the framework of the methodology.

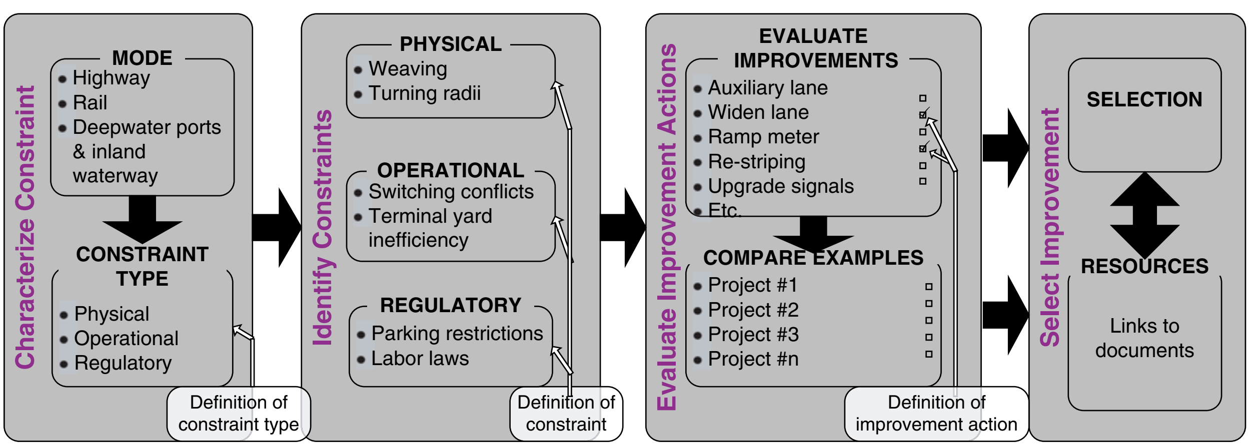


Figure ES-1. Framework of methodology.

Catalog of Improvements

The tool was applied to develop a catalog of low-cost actions or classes of actions that can be quickly implemented to address freight-system mobility constraints especially along corridors or at locations that impact freight mobility at a national level. The theme in developing the catalog of actions was to identify proven low-cost improvements that have the potential to enhance freight mobility to a noticeable extent even though such actions may not by themselves necessarily remove the constraint entirely. The catalog of improvements targets locations or corridors where major constraints within each modal freight transportation network occur. Improvements presented in the catalog are generic; however, implementation at a particular location would require consideration of specific site characteristics and operational practices. Similarly, given the uniqueness of each deepwater port, an effective action at one port may not necessarily be effective at another port.

Recommendations for Further Research

Recommendations are provided to enhance utility and usefulness of the tool. The methodology is data driven and therefore, to serve a useful purpose, the database needs to be continuously updated to remain relevant. It is therefore recommended to develop a mechanism for adding new project data to the database as improvement projects are implemented. No such mechanism currently exists to collect, process, and report low-cost freight mobility constraint improvement projects.

Furthermore, to facilitate updates to the database and enhance the future usefulness of the tool, it is recommended that the tool be converted to a web-based software application tool. A collaborative effort among public and private modal stakeholders will be needed to develop and utilize the data collection mechanism to facilitate continuous updates to the database.

The methodology was developed acknowledging that it would be integrated into the standard project development process, which each state department of transportation and metropolitan planning organization is required to have in order to use state or Federal funds to implement such projects. Further research is needed to develop the guidelines for integrating the tool with the project development process at the state and local levels.

CHAPTER 1

Introduction and Research Approach

1.1 Problem Statement

Freight transportation has been and continues to be a major contributor to the U.S. economy. Estimates indicate that the volumes of freight are expected to double over the next two decades in the United States. A report (*1*) noted that the nation's freight ton-miles by all freight modes increased steadily at an average rate of 1.2 percent per year between 1980 and 2004. The rapid growth in freight demand over the last 15 years has produced growing concerns regarding the capacity of the freight transportation system to support and sustain safe and efficient freight mobility. The increasing freight demand and capacity constraints present several challenges to the management and operation of the freight transportation system. The U.S. Department of Transportation (USDOT) estimates that volumes of goods shipped by trucks and railroads will increase over 2002 levels by 88 percent and 98 percent, respectively, by 2035 (*2*). During this time the ability to increase freight transportation capacity will be constrained by budgetary limitations, geographic barriers, population density, and urban land-use development patterns. The consequences of this increased freight demand and increased density include increased congestion, delay, air emissions, and operational costs, among others. Furthermore, evolving technologies, growing demand, changing business practices, shifting patterns of commerce, and government policies designed to address safety, security, environmental, and other public concerns may significantly affect transportation system performance.

Freight mobility is constrained not only by physical infrastructure inadequacies but also by operational, regulatory, policy, technological, and financial limitations. Federal, state, and local transportation agencies' ability to invest in system expansion and new system technology has been significantly constrained by inadequate revenue. The recent National Surface Transportation Policy and Revenue Study Commission (*3*) noted that the nation is investing only about 40 percent of the necessary levels to adequately sustain passenger and freight mobility. These factors have significantly increased interest in addressing freight mobility constraints through implementation of innovative operational strategies, performance-improving regulatory and policy changes, and low-cost capital improvements.

Recent studies and statistics document the inadequate capacity and increasingly costly congestion—not only on the nation's highways but also in metropolitan areas, at water ports, railroads, airports, and intermodal facilities. For example, the trucking industry faces increasing levels of congestion each year, including that resulting from poorly managed interactions between truck and automobile traffic on Interstate highways and local arterials, including traffic associated with intermodal terminals. As previously stated, the U.S. transportation network is operating at an unprecedented high level of traffic density. For example, the density of traffic on the highway system has more than doubled over the past 25 years with consequences that include increased congestion, delay, and air emissions. Over the same period, railroad network traffic density has nearly tripled (*4*). There is no single or simple solution for the mobility challenges. The approach should focus on the entire surface and maritime transportation system rather than mode-specific solutions. A system-wide approach to transportation planning and funding would yield desirable results. Severe congestion increases the costs and frequency of needed road maintenance, which in turn takes a toll on throughput and vehicle operating costs and productivity during the highway maintenance season.

Many innovative, low-cost improvements are being implemented independently by public and private stakeholders [e.g., state DOTs, Metropolitan Planning Organizations (MPOs), shippers, freight carriers, port authorities, terminal operators, railroads, and other groups of stakeholders] to address freight mobility problems to meet their specific needs. Although many promising strategies have been developed and implemented, they have not been well documented or evaluated for their possible applicability or scalability to other regions or localities.

Moreover, while public agencies have made substantial efforts to develop these strategies among different stakeholders and funding sources, implementation has been coordinated for the maximum benefits to be derived. Increasing the capacity of the existing freight transportation system through innovative operational and low-cost capital improvements and demonstrating these results will benefit both the public and private sectors, which are trying to keep the nation's freight moving in support of the national economy.

1.2 Research Objectives

The objectives of this project were to:

1. Develop a more standardized description of the dimensions of the freight system (e.g., elements of each mode and across modes, stakeholders, types of mobility constraints) that will help improve communication among freight-system decision makers and stakeholders. The goal is to facilitate examination of freight-system mobility constraints and the operational practices or system enhancements used to address these constraints.
2. Analyze explicitly the business practices and institutional factors that influence freight-system decision makers and stakeholders as they respond to freight-system mobility constraints, regulatory changes, and other public policy initiatives.
3. Develop a methodology that private- and public-sector decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, regulatory, and public policy actions focused on reducing system constraints.
4. Apply that methodology in a generic way to create a catalog of actions that may be most useful in addressing the nation's freight-system mobility constraints.

1.3 Research Approach

1.3.1 Overview

The project was divided into 11 tasks and grouped into three main phases. The project activities and deliverables in each phase and how they relate to the project objectives are shown schematically in Figure 1.

The first phase comprised the first five tasks. This phase established the baseline situation by defining the freight transportation system and designed a survey for collecting data necessary to develop a methodology for selecting low-cost implementable physical and operational improvements to the freight transportation system. This phase addressed the first two objectives of the project by developing a standardized description of the dimensions of the freight system. The effort was to help improve communication among freight-system decision makers and stakeholders and to facilitate examination of business practices and institutional factors, including regulatory and other public policy initiatives.

The second phase of the project (Tasks 6-9) used the survey design developed in the first phase to gather data and information, develop and test the methodology, and structure an implementation plan. This phase focused on the third objective of the project, namely to develop a methodology that private- and public-sector decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and public policy actions that can address system constraints and enhance freight mobility.

The final phase of the project (Tasks 10 and 11) focused on estimating the likely national value of actions or classes of actions addressing freight-system mobility constraints. This phase addressed the culminating objective of the project, i.e., to apply the methodology in a generic way to create a catalog of actions that may be most useful in addressing the nation's freight-system mobility constraints. This phase presented the project findings in this document, which includes a user guide for the software tool (Appendix A).

1.3.2 Data Collection

Three information-gathering approaches were used: (i) a literature review, (ii) telephone interviews and limited in-person interviews with selected representatives of stakeholders, and (iii) a survey of a convenience sample of stakeholders.

1.3.2.1 Literature Reviews

A comprehensive review of project reports and published technical literature and an Internet search were conducted. The purpose was to derive information on three key elements: (i) definition of freight mobility constraints, (ii) criteria for low-cost improvements directed at addressing freight mobility constraints, and (iii) sources of information on implemented projects.

1.3.2.2 Interviews

The purpose of the interviews was to gather sufficient information to help develop a better understanding of constraints facing freight transportation by different modes and the range of improvements taken to address these constraints. These interviews also identified sources of detailed information on examples of implemented improvements by various agencies.

The interviews preceded the survey and were designed to gather pertinent and detailed information that cannot be conveniently gathered through surveys, and to guide the development of a focused survey instrument. Such information includes decision factors in evaluating and selecting improvements, detailed project descriptions including cost,

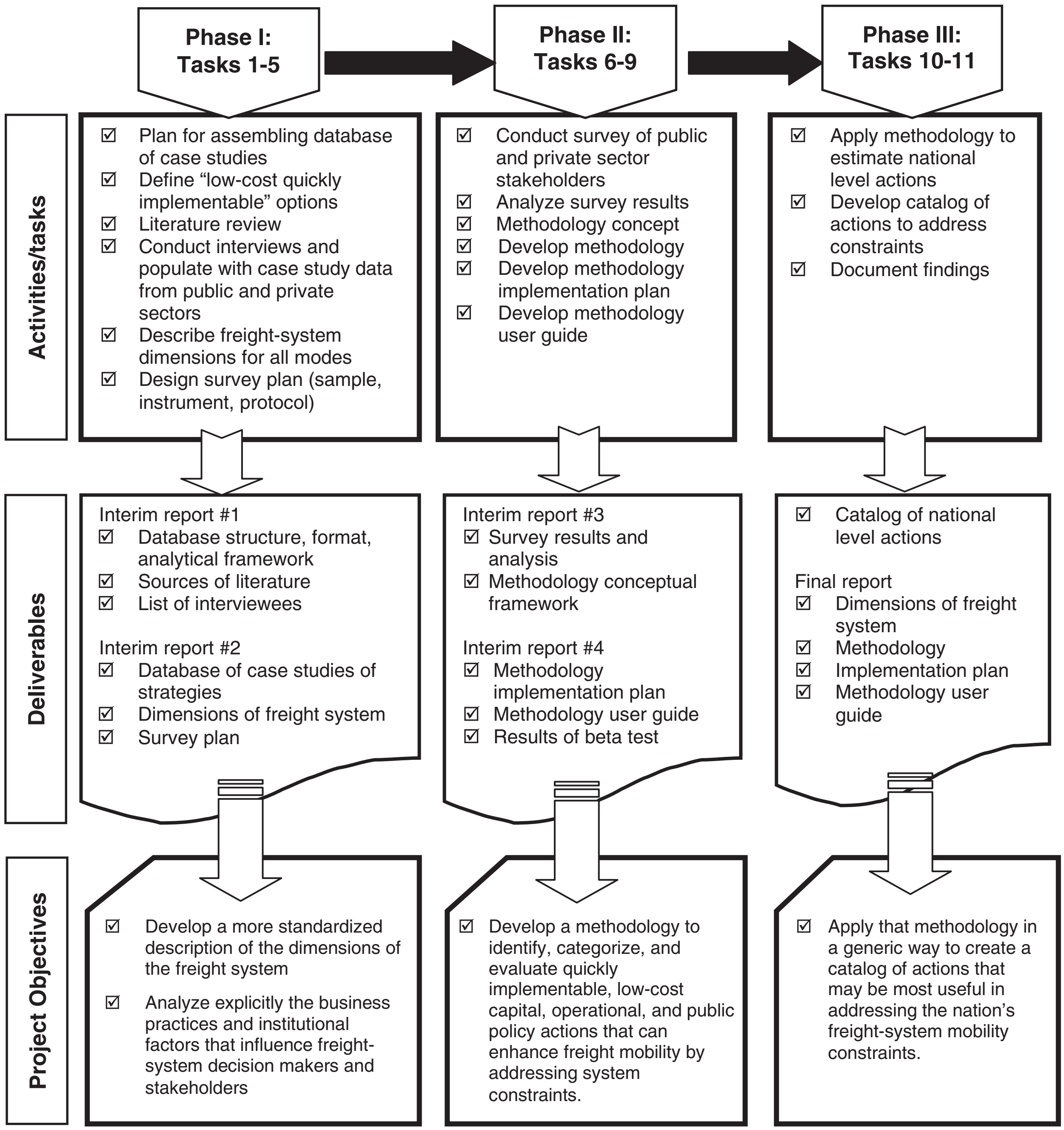


Figure 1. Relation between project tasks and objectives.

and expected versus actual impacts of improvements. The results of the interviews and survey complement each other.

Interviews were conducted with representatives of key stakeholders from both public agencies and private industry. These two groups of stakeholders represent public agencies (e.g., state DOTs, railroads) that provide and maintain the transportation infrastructure and private industry (e.g., truckers, shippers, freight forwarders, and warehouse operators) that operate and, for the most part, pay for infrastructure maintenance and improvements. These users are directly impacted by the mobility constraints and potentially will recognize the benefits of improvements taken to address these constraints. For the trucking industry, for example, targeted industry sectors included less-than-truckload (LTL), truckload (TL), and specialized carriers as well as third-party logistics providers (3PLs). Respondents were chosen to represent carriers with regional or national operations. Similarly for the railroads, a sample of Class I, regional, and short-line railroads were interviewed. Freight carriers of various sectors and scopes of operations were chosen to illustrate how mobility constraints affect carriers with significantly different operating characteristics. In addition, various labor unions in the freight industry were interviewed.

The respondents do not represent a statistical sample. However, they do represent a cross section of the various segments of the freight transportation industry and they provided remarkable insights and diverse information on the issues of interest to this project.

The questions in the interview guide (Appendix C) were framed with the assumption that the data collection effort would capture information on case studies where low-cost improvements have been implemented or are currently in the process of being implemented. Respondents were provided interview questions prior to the interview. Responses to questions in the interview guide were recorded to the highest level of detail possible. The respondents were asked to review interview notes for accuracy and completeness.

Information was also gathered through a workshop conducted during the annual meeting of American Association of State Highway and Transportation Officials' (AASHTO) Subcommittee on Design (SCOD) held in Albuquerque, New Mexico, in July 2008 to engage SCOD members on the issue of low-cost improvements for freight mobility. The participants included representatives of state DOTs, the Federal Highway Administration (FHWA), and an individual from the British Columbia Ministry of Transport, Canada.

1.3.2.3 Survey

The purpose of the surveys was to gather information from public- and private-sector stakeholders regarding their perceptions, attitudes, and practices to address freight-system mobility constraints. The survey plan had three main components: (i) protocol – an Internet survey approach was used because of its relatively high response rate and ease of compiling and analyzing survey data; (ii) survey instrument – the questions were specifically structured consistent with the protocol, i.e., Internet survey; and (iii) sampling plan – the approach to reach a representative sample of potential respondents.

A dedicated website was created for this survey. This site was monitored continuously throughout the duration of the survey. The protocol was coded to prevent the same survey respondent from completing multiple surveys. The survey instrument (Appendix D) comprises a general section (all respondents are expected to answer) and mode-specific sections (directed primarily at private-sector stakeholders) as follows:

- Motor carriers
- Railroad companies
- Deepwater ports and inland waterways
- Labor unions, shippers, and warehouse operators.

The format of the survey was designed to encourage private-sector stakeholders to complete the survey by directing them to questions that are directly related to their respective operations. Federal, state, and local transportation agencies were asked to complete the entire survey but to focus on the general section.

The goal was to reach a fairly large sample of representatives of the various entities involved in freight transportation by working with industry associations and other organizations to help invite members to complete the survey. The target audience included public- and private-sector groups, i.e., state DOTs and MPOs; a cross section of national, regional, and local motor carriers; Class I, regional, and short-line railroads; port terminal operators; logistics service providers; shippers; freight forwarders; and labor unions. For example, the American Transportation Research Institute (ATRI) invited motor carrier representatives through its website; the link was also sent to project advisers at Kansas City Smart Port to invite its members to take the survey. Invitations to take the survey were also sent directly to those listed in the national state DOT freight directory, MPOs, and AASHTO state rail contacts. The invitees were encouraged to forward the survey link to their colleagues to complete the survey.

1.3.3 Data Analysis

Both qualitative and quantitative analyses were conducted on data collected through stakeholder interviews and surveys. The qualitative analysis involved preparing a summary of the data elements necessary to populate the database of low-cost improvement projects. This includes summary descriptions of constraints, performance indicators used in monitoring and identifying constraints, definitions of low-cost, quickly implementable solutions, decision factors in selecting improvements, factors for evaluating improvement projects, lessons learned, and sources of further information.

Standard statistical analysis principles and methods were used in analyzing quantitative data obtained from the survey. First, survey weights were used to adjust for any biases that may occur due to the sample selection and to expand the sample results to the target population. Based on the estimated number of potential survey takers from each group of stakeholders and the number included in the email invitation, sample weights were calculated and applied to adjust the results for non-response, and then post-stratified to adjust to the target population. The product of these adjustments represents the final analysis weights that were applied to the samples of each category to ensure that the results from the sample are representative of the target population.

Descriptive statistics such as weighted averages, frequencies, and percentages were used to characterize the survey responses. Separate analyses were conducted for each of the three primary modes (highway, rail, and water) while distinguishing between public- and private-sector perspectives to the extent possible.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter documents previous research and practices regarding freight mobility issues. For each of the three principal surface transportation modes of freight movement, the literature review attempts to capture definitions of mobility constraints, definitions of low-cost improvements, and strategies to address mobility constraints. Finally, the literature review documents examples of low-cost improvements implemented to improve freight mobility. An annotated bibliography is also provided in Appendix B.

2.2 Highways/Trucking

2.2.1 Defining the Freight Mobility Problem on Highways and Roadways

A number of factors contribute to constrained freight mobility, which, when combined, have significant adverse economic, environmental, safety, and security impacts. One factor is the growing demand for freight transportation, as reflected by the increasing volume of domestic and international freight that is moved on the nation's transportation system.

According to USDOT estimates, the volume of goods moved by truck and rail is projected to increase 98 percent and 88 percent, respectively, from 2002 levels by 2035. As a result of increasing freight demand, congestion is rising and is expected to increase in the future. This congestion will have a number of negative impacts. For example, producers, shippers, and consumers will suffer the higher economic costs of an inefficient freight transportation system (*5*).

FHWA (*6*) categorized freight mobility problems related to bottlenecks in the following four constraint types:

- Interchange constraints
- Highway capacity constraints
- Geometry constraints (i.e., steep grade)
- Intersection-related constraints.

In addition, non-recurring events are also known to contribute to delay. The most common of these events are listed below along with the percentage share of each event type (*7*):

- Non-fatal crashes (45.5 percent)
- Work zones (24.3 percent)
- Breakdowns (12.0 percent)
- Weather (9.0 percent).

Freight mobility constraints can be caused by physical, operational, or regulatory factors. Recent National Cooperative Highway Research Program (NCHRP) Project 3-83, "Low-Cost Improvements for Recurring Freeway Bottlenecks," identified the following as some of the physical or geometric features that contribute to the occurrence of freeway bottlenecks (*8*):

- On-ramp sections with no auxiliary lane additions or with short deceleration lanes
- Weaving sections, particularly out of dropped lanes
- Lane drops on basic segments, or following off-ramps or tunnel sections, where free flow speed may be reduced
- Horizontal curves, where vehicle paths may cross into the next lane
- Long upgrades, particularly in the presence of heavy vehicles
- Narrow lanes on older freeways
- Lateral obstructions, which reduce free flow speeds.

2.2.2 Definition of Low-Cost Highway Improvements

While certain improvements may be considered as low-cost, there is no general definition of the characteristics of such activities. The Minnesota DOT (*9*) used the following four criteria to identify "short-term, low-cost congestion-reduction strategies" for specific bottleneck locations:

1. Projects were required to have the potential of a 50 percent reduction in congestion

2. Project timelines were required to be within 2–3 years
3. Costs were required to be less than $15 million
4. Safety could not be decreased as a result of the project.

Latham and Trombly (*10*) defined low-cost traffic engineering improvements to be "project(s) or strategy(ies) that generally [require] an investment in the range of $10,000 to $50,000." The authors also noted that "Low-cost traffic engineering improvement techniques are typically spot applications or are limited to shorter sections of roadway that do not cover an entire length of an arterial corridor. Some of these strategies include pavement markings, static and dynamic signing, roadway lighting, raised medians, curb cuts, roadway geometric changes, or lane controls. These strategies provide the guidance, warning, and control needed for drivers to ensure safe and informed operation through traffic bottlenecks or congested areas."

Regardless of cost, three categories of improvements are identified in the literature: (i) physical, geometric, and engineering improvements; (ii) operational and technology improvements; and (iii) regulatory- or public policy-based improvements. The following sub-sections describe these three categories and illustrate them with examples.

2.2.3 Examples of Physical Low-Cost Improvements

Walters et al. (*11*) documented three case studies in Texas that are considered to be low-cost improvements.

1. Improvements to a section of an urban highway where weaving and horizontal curve problems occur. To address the problem, an exit ramp was replaced with an entrance ramp to remove the weaving problem at a cost of $660,000. The improvement reduced the cost of delay on the ramp by $700,000 annually.
2. Mobility constraint due to lane drop and weaving on a congested exit ramp. The low-cost improvement was to add an auxiliary lane so that the entrance/exit lane did not end at the exit. This required a change in the designated use of an outside shoulder. The total cost was $150,000. The benefits in delay mitigation were calculated to be $200,000 annually.
3. Addition of a lane to the inside shoulder in a highly congested urban highway to add capacity. The cost of this additional lane was approximately $130,000, the majority of which was reported to be spent on re-striping the section of highway. The delay reduction benefits were calculated to be $600,000 annually, and there was an additional safety benefit found through a decrease in crashes at the location.

FHWA (*12*) also reported that similar low-cost improvements implemented elsewhere mitigated congestion. Examples include the following:

- **Truck-Related Bottleneck in Washington State—**Washington SR 167 in Federal Way in the Puget Sound region exhibited a bottleneck caused by a steep grade that dramatically reduced truck speeds. A lane was added on the grade to accommodate slow-moving trucks.
- **Florida—**An interchange with short weaving sections caused queuing on the ramp that often extended to the freeway mainline. The problem was addressed by adding a right-turn lane and a signalized right-turn lane.
- **Maryland's Quick Fix at Interstate 70/Interstate 695—**Inadequate capacity of the I-70/I-695 interchange outside of Baltimore, Maryland, resulted in traffic on the eastbound approach from I-70 to I-695 backing up on to the mainline of I-70, restricting flow of through traffic. A quick-fix solution was to widen the ramp up to the bridge. This provided adequate storage to relieve the backup onto the mainline.

To reduce delays and improve highway access to a major intermodal facility, Corwith Yard in Chicago, Illinois, the signal system at the intersection was updated and synchronized to allow trucks to make turns safely. These improvements eliminated the delays to trucks getting into the yard (*13*).

2.2.4 Low-Cost Operational/Technology Improvements

FHWA (*14*) suggests that improving the management and operations of transportation systems is a cost-effective way to influence the bottlenecks that affect freight. The following 12 low-cost operational remedies have been identified (*12*):

1. Using a short section of the shoulder as an additional travel lane
2. Re-striping the merge/diverge areas to better serve demand
3. Reducing lane widths to add a travel and/or auxiliary lane
4. Modifying weaving
5. Metering or closing entrance ramps
6. Speed harmonization (adjusted speed limits when congested)
7. Zippering, self-metering that promotes fair and smooth merges
8. Improving traffic signal timing on arterials
9. Improving arterial corridors using access management principles
10. High Occupancy Vehicle (HOV) lanes
11. Providing traffic diverging information
12. Implementing road pricing to bring supply and demand into alignment.

Ramp metering was ranked as the most utilized low-cost operational improvement among transportation agencies. This is followed by auxiliary lanes and then HOV lanes. In general, the study results suggest a trend toward ramp metering as a low-cost bottleneck improvement (*12*). The practice is said to both decrease delay and to decrease the number and severity of crashes (thus decreasing traffic incident delay). To assess the benefits and costs of ramp metering, Minnesota DOT conducted a test of the effectiveness of the system that is deployed in the Twin Cities region. Several of the ramp meters were turned off during this experiment, and increases in delay, along with decreases in safety, were the end result; it was determined through this study that use of ramp metering in the Twin Cities saves $40 million annually (*15*). The greatest benefits of such a system for the trucking industry are likely found on trips through urban areas, where trucks would face fewer and less severe bottlenecks caused by vehicles that are entering the highway.

Interviews of state and local transportation agencies (*8, 12*) showed that the addition of auxiliary lanes ranked second among participants, and is listed as a good solution to the following issues:

- Heavy on-ramp demand
- Lane drops
- Horizontal/vertical curves
- Inadequate accelerated and/or decelerated lanes.

The Government Accountability Office (GAO) (*5*) suggests that "limited parking for delivery to be received adds delay" to freight movement. It can be inferred from this statement that a low-cost method of increasing freight mobility/efficiency at the point of delivery is therefore to remove automobile parking and/or designate freight delivery parking areas.

Changes to the characteristics of signals are also discussed in the literature. Low-cost improvements to traffic signals to prevent crashes (and subsequently increase mobility) include:

- All-red intervals
- Installation of 12-inch signal heads (increased from 8-inch)
- Installation of additional signal heads at a different level (e.g., post mounted)
- Changing location of traffic signals, or adding back plates to increase visibility (*10*).

Signal improvements have been successfully used to increase the efficiency of left turns in Maryland. At an approximate cost of $5,000 per improvement, the state has implemented the following improvement types:

- Two turn phases per cycle
- Half-cycle variation
- Directional lead-lag (*10*).

GAO (*5*) found that traffic incident management programs have the ability to increase freight mobility through the efficient clearing of accidents and restoration of vehicle movement along roadways. Dunn and Latoski (*16*) also offered several low-cost, training-based examples of traffic incident management enhancements, including:

- Integrating private towing and recovery companies into training programs
- Training approaches such as video and stakeholder-specific instructional presentations
- Incident management response team debriefings to identify lessons learned.

Traveler information is available in several forms (e.g., changeable electronic message signs, radio broadcasts, 511). Commercial motor vehicle operators may have additional sources of information as well, including the support received through dispatchers and other trucking operations personnel, as well as through communications with other truck drivers (e.g., over CB radio or cell phone).

FHWA (*17*) identified several types of information that can be disseminated to travelers in order to decrease congestion in certain areas, including:

- Weather information
- Variable speed limit signs
- Information related to roadway diversions, alternative routes, emergency evacuations, and construction.

Systems such as 511 and electronic message signs can provide details on traffic incidents and travel times. Whether or not to categorize such activities as low cost is debatable. In a large metropolitan area, for instance, the initial cost of a 511 system is estimated to be over $40 million, with annual costs of approximately $2.5 million (*18*).

Finally, work zone management techniques can have an impact on freight mobility issues related to highway construction. As an example, work zone management software, weekend and night construction, and incentives for early completion can successfully decrease the time in which a section of roadway is disrupted (*19*).

2.2.5 Examples of Low-Cost Operational Improvements

- **Georgia DOT's Low-Cost Efforts to Improve the Atlanta Downtown Connector—**In this example, low-cost improvements were implemented to reduce delay and improve mobility on a 4-mile section of downtown freeway connector in Atlanta, Georgia. The improvements include restriping and extension of a divider wall to add ramp storage and reduce weaving at three ramps and installation of four southbound entrance ramp meters in that section. The result was that the ramp meters saved a weekly average of

22.4 percent in time during the afternoon peak period. Between 2004 and 2005, the number of severe congestion hours was reduced by 37.7 percent (*12*).

- **Syracuse, New York—**Traffic signals were upgraded at 145 locations with the following results:
  - 15.7 percent decrease in stops
  - 16.7 percent reduction in travel time
  - 18.8 percent reduction in delay (*9*).

  It was found that the cost of optimizing traffic signals ranges from $500 to $3,000 per intersection, while the benefit to trucks moving within the City of Syracuse is likely valued much greater on an annual basis.
- Latham and Trombly (*10*) documented several examples of low-cost operational improvements that have potential to address mobility constraints. The following are a few examples:
  - **Florida on US 1**—by decreasing the number of median openings, fewer vehicles create slow-downs in left-lane traffic by exiting, entering, and even crossing traffic by use of a median. Such a change also likely has safety benefits for trucks as well.
  - **Detroit, Michigan**—an exclusive left-turn lane was added at one intersection, along with other minor improvements including signal upgrades, at a cost of $36,100. Such an improvement has the potential to allow cars and trucks to turn left in a faster manner and may decrease traffic signal queues.
  - **The City of Knoxville, Tennessee, Traffic Engineering Department**—has successfully implemented a number of low-cost traffic engineering improvements over the years, e.g.,
    - Installing sight distance mirrors, where more expensive earthwork to remove the sight distance obstacle is not feasible
    - Providing longer all-red intervals in the signal timing where such things as bridge decks interfere with signals
    - Placing signal heads to provide a better view of red signals in locations with limited sight distance to signal faces
    - Providing narrower lane widths to provide additional lanes
    - Providing detector-actuated flashers for sight distance problems that would require very expensive earthwork to correct.
  - **The Public Works Department of the City of Springfield, Missouri**—installed and evaluated low-cost traffic engineering improvements to correct safety problems at intersections. These treatments range in cost from $150 to $5,000, e.g.,
    - Install mast arm to mount signal heads overhead to improve visibility
    - Install lane use signs
    - Realign signal and relocate "Stop Ahead" sign to improve visibility.
  - **Detroit and Grand Rapids Low-Cost Improvement—**American Automobile Association (AAA) Michigan initiated a program to identify and treat locations in the cities of Detroit and Grand Rapids with frequent crashes and congestion. Over the past six years, AAA Michigan examined 253 intersections and low-cost safety improvements were implemented at 112 sites. Actions implemented at the intersections included the following:
    - Implementation of all-red intervals
    - Replacement of 8-inch signal heads with 12-inch signal heads
    - Relocation of signal heads to improve visibility by realigning two signal heads facing each other, realigning the signal heads over each lane of travel, or mounting the signal heads using box span installations
    - Installation of secondary post-mounted signal heads to improve visibility at some locations
    - Installation of back plates on traffic signals to improve visibility at some locations
    - Installation of left-turn lanes through re-striping of approach lanes and exclusive left-turn phases, where needed
    - Removal of on-street parking.

2.2.6 Low-Cost Regulatory/Public Policy Improvements

One approach to improve freight mobility with a low-cost focus involves changes in regulation. Adding new rules and regulations governing the use of the freight transportation system may in turn decrease congestion, thereby improving freight mobility. Regulatory changes and public policy-oriented programs can be utilized to modify traveler behavior, and thus mitigate freight mobility constraints. Most notably, such programs and laws can address capacity issues that cause congestion by decreasing the annual vehicle miles traveled (VMT) of passenger vehicles, and thus increase the effective "supply" of highway for use by freight operators. An example of this is found in a GAO report (*20*), which cites several public policy-based solutions to surface transportation mobility constraints that could improve freight mobility, including using public information and programs to encourage the following:

- Use of mass transit
- Carpooling
- Teleworking.

From a public-sector position, such programs are low cost and quickly implementable, especially in comparison to multi-million dollar infrastructure projects. The most effective tool of governance used in such a situation is public information, such as advertising campaigns to encourage use of mass transit, telecommuting, or similar changes in behavior. Use of additional tools such as local, state, and Federal tax expenditures that benefit participating companies, and encourage additional participation, will add to the cost of such programs. The end result, however, may be beneficial to freight mobility.

Transportation finance mechanisms also play a role in freight mobility. The cost of tolls, for instance, often cannot be passed from the for-hire trucking sector to customers. Thus, a toll road often presents itself to the industry as a mobility constraint, especially when the decision is made to bypass a tolled interstate as a result of the low willingness to pay among trucking companies (*21*). A low-cost, quickly implementable solution to such constraints may be found through the use of simple and more traditional methods of collecting highway revenue (e.g., motor fuel taxes).

Finally, there has been a growing public policy discussion (*22*) related to changes in size and weight regulations for commercial motor vehicles. The focus of the discussion is to increase the size of truck configurations (through, for instance, increased use of double and triple trailer configurations) and weight (by allowing more weight than is currently legal without requiring a special permit), which has the potential to result in the movement of the same amount of freight that is currently moved, but with fewer tractors and lower emission rates per ton-mile. The benefits of such a policy change may be felt the greatest at freight origins and destinations, where space can often be limited. In addition, there are likely significant benefits in long haul operations.

2.2.7 Examples of Low-Cost Regulatory Improvements

- **Downtown Chicago Facility Regulations**—Many buildings are considered freight traffic hotspots due to inadequate loading facilities. O'Laughlin et al. (23) suggest the following standard policies for new buildings, intended to improve the efficiency of freight mobility:
  - Comprehensive loading zone plan—e.g., physical inventory of loading zones
  - Use metered freight loading zones (with graduated fees)
  - Add loading zones in "hot spots"
  - Designate areas with on-street parking as loading zones before 9 or 10 AM
  - Increase parking violation fines during rush hour for obstructing traffic movements
  - Initiate an enforcement program focused on non-commercial vehicles parked in dock areas
  - Distribute promotional materials to buildings with "where to call" information (reporting violations).

2.3 Railroads

2.3.1 Freight Capacity

Rail infrastructure consists of track and structures, terminals or yards, locomotives, cars, and signals. The Tioga Group (*24*) identified major factors affecting railroad capacity to include:

- Number of tracks
- Number and length of sidings
- Number of crossovers and other connections
- Type of signaling
- Speed limits
- Grade and curvature.

Shortages of freight rail cars or locomotives also reduce the capacity of the rail system. Similarly, excess numbers of cars and locomotives can be costly to rail operations. Between 1985 and 2005, the number of rail freight cars stabilized between 1.2 million and 1.4 million, while the average capacity of rail cars grew from 53.7 tons to 97.2 tons (*25*). Also the number locomotives increased by about 27 percent between 1992 and 2005 (*4*). This is a reflection of the continuous growth in freight demand and the use of freight cars with greater maximum payloads. Also, better signaling and communication help improve utilization of existing tracks. Thus constraints to the movement of freight by rail can be defined in terms of these infrastructure components in addition to labor components that together provide rail services.

According to a recent study (*26*), investment requirements for rail are driven by three factors: demand, current system capacity, and infrastructure expansion costs. USDOT estimates that the demand for rail freight transportation will almost double by 2035 with 2002 as the base year. The growing demand for freight transportation has direct impacts on the capacity of the rail freight system. Freight shippers and carriers are especially concerned about the future capacity and productivity of the freight system. In addition to the growing demand for freight transportation, increasing congestion on the highway system could cause some freight to be diverted to rail. However, escalating time constraints to move shipments or raw materials through the supply chain may minimize these diversions. To absorb the growth, it was estimated that railroads must add capacity to handle tonnage 88 percent above current volume.

Major rail infrastructure improvements relate to line and facility expansion. Line expansions include:

- Upgrades to the Class I railroads mainline tracks and signal control systems
- Improvements to significant rail bridges and tunnels (construction of new parallel bridges and tunnels, overhead

clearance projects which typically involve raising highway bridges crossing rail lines to permit movement of double stacked intermodal container trains)
- Upgrades to short-line and regional railroad tracks and bridges to accommodate heavier (286,000 pound) freight cars.

Facility expansion includes:

- Expansion of carload terminals, intermodal yards, and internal gateway facilities owned by railroads
- Expansion of Class I railroad service and support facilities.

Rail line capacity is determined by the following factors:

- Number of tracks—double track allows trains to pass in opposite directions without stopping
- Number and length of sidings
- Type of signaling—centralized traffic control yields higher capacity
- Speed limits
- Grade and curvature
- Traffic mix.

According to Immel and Burgel (*27*), measures of performance would include:

- Average speed
- Hours of delay
- Delay ratio.

2.3.2 Freight Mobility Constraints

Railroads are beginning to experience severe capacity constraints in areas where commuter and intercity passenger rail services share tracks with freight railroads (*28*). The following are some rail freight mobility constraints identified in the literature.

- Inadequate sidings
- Switching conflicts especially for mixed-speed operation on single or dual track
- Yards and port terminals
- Lack of funding for track upgrades
- Outdated communication and signaling systems.

Immel and Burgel (*27*) noted that rail capacity is also affected by (i) speed and length of trains, (ii) differing priorities, and (iii) the number and types of facilities in the same area served by the rail lines. Thus, adding capacity may require changes in operating practices and investment in tracks, signals, and other facilities that directly impact capacity.

A recent study (*26*) examined current levels of rail freight capacity. It focused upon the 52,340 miles of primary rail corridors, which carry the majority of the nation's freight traffic. Although the large majority of the current system is operating at an acceptable level of service, the amount of excess capacity on the rail network has diminished through two decades of growth, the study reports. It forecasts that if the 2035 rail freight volumes were to occur on today's rail network, 30 percent of the major rail network would be operating above capacity and creating severe congestion. Because of the interrelated nature of the nation's rail network, this congestion would affect every region of the country. The cost to keep pace with the level of growth was estimated to be $148 billion in constant dollars through 2035. Of this amount, the study estimates the railroads could contribute about $96 billion from expected income and operations. That leaves an investment gap of $39 billion, or $1.4 billion annually, to meet the rail capacity needs through 2035.

2.3.3 Low-Cost Improvements

There is no clear definition of what constitutes a low-cost action or strategy directed at addressing freight mobility constraints in the available literature. However, certain improvements to rail capacity are obviously needed to accommodate future freight growth. The cost of these improvements varies from low to very expensive. Some of the improvements that could be considered "low-cost" because they fall within the low end of the cost spectrum include:

- Track improvements, e.g., improve passing sidings
- Changes in control types (e.g., from No Signal to Centralized Traffic Control)
- Upgrade of communication system
- Track maintenance
- Branch line upgrades
- Expansion of carload terminals
- Joint use of facilities—pairing mainlines to provide directional running thereby increasing capacity
- Trackage rights agreements to improve efficiency of operations without necessarily increasing capacity
- Use of larger cars—further improvement may not be possible, at least for the Class I railroads. This option is also limited by capital/operating cost trade-offs.

The development of high-speed rail corridors, additional main lines, strategic overhead grade crossings, remote switching from the cab, and radar in all locomotives to prevent rear-end collisions now presents a unique opportunity to develop an extremely efficient intermodal freight system with substantial energy, environmental, and competitive advantages that will benefit all modes of transportation and help mitigate capacity issues.

2.3.4 Examples of Low-Cost Rail Improvements

The following are some examples of improvements that could be classified as low-cost and quickly implementable and that have positive impacts on freight mobility. Even though these projects are not specifically classified as such, the cost, in relative terms, and the period of implementation would satisfy the requirements of such a definition.

- **Chicago Region Environmental and Transportation Efficiency Program (CREATE) Project EW-4: BRC/NS Signal Upgrade**—This project involved upgrading the Belt Railway Company of Chicago (BRC) and Norfolk Southern (NS) signal systems to power switches and signals along a segment of track. The result of this improvement is that average train speeds increased from 10 to 20 miles per hour. The bottleneck at this location is now significantly alleviated as this segment can handle twice the number of trains, an increase from 23 to 46 freight trains per day (*29*).
- **Improve Passing Siding: West Durban, North Carolina**—Upgraded and extended the passing siding track in West Durban from 6,500 feet to more than 9,000 feet. Realigned track to straighten curve to increase speed from 45 mph to 65 mph and accommodate two tracks. Constructed a total of 12,500 feet of new track. The existing track became the new siding. No. 20 turnouts were installed to allow all trains to travel faster through the siding. The cost was $3.6 million. Extending the siding improved capacity and reliability of service and saved 30 seconds of travel time per train (*30*).
- **Install Traffic Control System, North Carolina**—A new centralized train traffic control system was installed between Greensboro and Cary, North Carolina, to automate train dispatching, improve rail capacity, and increase train speeds from 59 mph to 79 mph. Cost was $8 million. The result is improved traffic flow and reliability allowing trains to operate at a maximum speed of 79 mph saving 5 minutes of travel time per train (*30*).

2.4 Water Ports and Inland Waterways

This section presents a synthesis of published information on freight mobility issues regarding freight transportation through the sea ports, inland waterways, Great Lakes, and intercoastal waterways.

2.4.1 Marine Transportation System

The marine transportation system (MTS) is defined to include interrelated components of the national transportation system, such as shipping, ports, inland waterways, and their connections to rail and highway transportation modes and system. MTS includes 361 public and private deepwater and intercoastal waterway ports and over 24,000 miles of inland and coastal navigable waterways (*28*). There are about 70 deep-draft port areas along the U.S. coasts (*31*). Within these ports there are about 2,000 major terminals that are mostly privately owned and operated (*32*). While deep sea routes are the primary means of moving international freight, the rivers, coastal, and Great Lakes waterways are equally important means of moving domestic freight and for providing outbound feeder traffic for international shipping (*33*).

2.4.2 System Capacity

Knatz (*34*) noted that port capacity has two important dimensions: the short-term capability to respond to interruptions in the supply chain and the ultimate capacity to handle the nation's long-range forecasts of trade. GAO (*35*) also observed that the U.S. maritime freight transportation system primarily consists of waterways, ports, the intermodal connections (i.e., inland rail and roadways) that permit freight to reach maritime facilities, and the vessels and the vehicles that move cargo within the system. The marine infrastructure is owned and operated by an aggregation of state and local agencies and private companies with some Federal funding. International freight is an important aspect of the U.S. economy. The U.S. surface and maritime transportation systems facilitate mobility through an extensive network of infrastructure and operators as well as through the vehicles and vessels that permit passengers and freight to move within the systems.

The U.S. Maritime Administration (MARAD) (*28*) noted that as larger ships put increased pressure on ports, greater container volumes and customer expectations would require an effective, efficient, and integrated total transportation system. For inland waterways, there is sufficient capacity, although congestion is increasing at small, aging, and increasingly unreliable locks.

Port terminals function as nodal points within MTS with the basic function of transferring and storing freight. Le-Griffin and Murphy (*36*) noted that as the demand for international trade and global logistic services continues to increase, port capacity can be expanded by improving productivity and operational efficiency of terminal facilities.

2.4.3 Performance Indicators

Ports are dissimilar and even within a single port the current or potential activities can be broad in scope and nature, so that the choice of measure of performance can be difficult. There is no acceptable standard method of measuring performance that is applicable to every port (*37*). Inconsistencies in performance data make it difficult to compare operational efficiencies of U.S.

ports. Factors affecting port efficiency, which is a reflection of freight mobility, include the following (*28*):

- Labor efficiency (cargo moved per unit of labor)
- Land use efficiency (cargo storage per unit of land)
- Waterside access limitations
- Capacity of port road and rail connections
- Inland transportation availability
- Cargo handling capability.

Le-Griffin and Murphy (*36*) further noted that the external factors influencing the productivity of container terminal operations include landside capacities and performance of intermodal rail and highway systems. Indicators of terminal gate productivity measures are gate throughput measured by container/hour/lane and truck turnaround time measured by truck time in terminal.

2.4.4 Mobility Constraints

As freight demand increases, congestion is expected to increase on major freight transportation networks, particularly where intermodal connections occur. Furthermore, with increasing international trade and with larger container ships being built, there will be more pressure on the already congested road and rail connections to major U.S. seaports. The constraints and/or challenges facing port terminal operators, shippers, and other stakeholders involved in international shipping and domestic freight movement by mode include the following (*28*):

- Poor or inadequate rail infrastructure—Congestion to rail shipments—common impediments include low overpass bridges that restrict specific rail cars; availability of single-track/single-operator port service; mainline rail terminals and yards that are distant from ports; lack of on-dock rail handling facilities
- Lack of staging areas especially during peak cargo flow
- Landside access—congestion on highway approaches to ports; turning lanes and radii on local roads are of increasing concern
- Maintenance dredging
- Lack of state and Federal funding
- Intermodal connectivity
- Inadequate or unclear highway signage for port terminal and access routes
- Connectivity—rail infrastructure connections at ports are often privately owned—these present special challenges for coordination with the Class I rail carriers and motor carriers
- Inadequate communication between terminal operators and drayage trucking firms; also communications among Federal agencies within a given port cause delays
- Difficulty of effective management and operation of the transportation system
- Funding is mode specific, and congestion at intermodal connections is not easily addressed.

2.4.5 Low-Cost Improvements

There is no clear definition of what constitutes a low-cost action or strategy directed at addressing freight mobility constraints in the available literature. However, the following actions directed at improving freight mobility (*28*) could be characterized as such given the potential relatively lower costs compared to massive projects associated with seaport terminal projects:

- Operational Strategies
  - More efficient port utilization—make the port "agile" by using "sprint" trains to take intermodal cargo directly from dockside to more remote inland locations for storage and sorting prior to distribution. The expectation is increased cargo capacity on waterfront acreage without the necessity of new construction, new equipment, or changes in labor.
  - Improved signage—Poor signage results in unproductive time spent on roads, increased fuel consumption, and increased cost of shipping. While better signage will not eliminate traffic congestion, it could provide an effective short-term solution to reduce some highway congestion and improve safety.
  - Disparate communication systems that are typically user or mode specific and that lack horizontal interfaces with other partners involved in the shipping process.
  - Expansion of terminal gate hours, e.g., through the PierPASS program.
- Physical Strategies
  - Modernize locks and dams to regulate water flow and facilitate commerce (inland waterways).
  - Improve marine terminal capacity and access to rail, road, and pipeline.
  - Deploy advanced computer, communications, and navigation technologies.
- Regulatory Strategies
  - Increase number of hours and shifts that terminal gates are open.
  - Reduce container dwell time.

2.4.6 Examples of Low-Cost Improvements

Most low-cost improvements to address freight mobility constraints encountered at the deepwater ports and on the inland waterway system are typically economic-incentive–based programs that influence demand, changes that improve efficiency of operations and processes (including the use of advanced technologies), and projects that encourage modal shift. Physical improvements are coordinated with highway and rail improvements both within and outside the terminals. The following are examples of such programs:

- **Congestion Pricing—**The PierPASS OffPeak program was implemented in July 2005 at the Ports of Los Angeles and Long Beach, as an incentive-based program to shift movement of international containers from peak weekday hours to evenings and weekends. All 12 international container terminals in the two ports established five new shifts per week (Monday–Thursday: 6 PM to 3 AM and Saturday: 8 AM to 6 PM). Traffic Mitigation Fees of $50 per 20-foot container and $100 per all other sizes of container are charged for daytime peak hour movements (Monday–Friday: 3:00 AM to 6:00 PM) (*38*).
- **Trucking Appointment System**—Many terminals in the United States, Latin America, and Europe use an Internet-based system (e.g., Forecast® system) to provide real-time information for trucking companies to streamline gate processing, enhance truck driver turntime, and reduce customer service costs. Shippers, consignees, brokers, and others receive advance information on import container availability, vessel schedules, activity reports, and booking status. This program enables improved planning and resource management and streamlines gate transactions (*39*).

CHAPTER 3

Dimensions and Characteristics of the Freight System

3.1 Introduction

The dimensions of the North American freight transportation network reflect the dimensions and needs of the North American economy. The U.S. economy is closely tied to the Canadian and Mexican economies, and increasingly relies on international trade. For example, trade with China grew from $85 billion in 1998 to $343 billion in 2006, representative of recent trade patterns (*40*). In total, transportation and its related components compose about 11 percent of the total U.S. economy, according to the USDOT (*41*). Consequently, the freight transport network in the United States has evolved to serve not only the increasing domestic freight demand but also an even higher increase in international freight movement. However, the rate of growth in freight demand has outpaced the rate of transportation infrastructure capacity expansion and maintenance funding levels. This chapter describes the dimensions of the freight system in terms of (i) the physical infrastructure and modal characteristics and (ii) freight mobility constraints.

3.2 Networks and System Characteristics

This section describes the nature of the freight transportation network for highways, rail, and water modes. To systematically address freight mobility issues it is necessary to describe and understand the dimensions of the freight system. Some of the literal dimensions of the physical freight transportation system are depicted in Table 1. These represent physical infrastructure and important components of the freight transportation system. Another important component is illustrated in Table 2, which highlights some of the physical rolling stock—trucks, locomotives, ships, airplanes, and other vehicles that carry freight across the network (*41*). A third component could be considered the "Intellectual Infrastructure." This includes the logistics processes, the technology systems, the inventory-control systems, and the body of knowledge that shippers, producers, and logistics personnel use. These three components influence one another, as shippers and carriers react to congestion, distance, price, and customer demands to choose the most efficient mode and route. The following sections describe these three components for the various modes.

3.3 System Performance

With the emergence of significant roadway congestion and mobility constraints and recognition of the criticality of freight movement to the nation's economy, there is a renewed emphasis on the development of freight performance measures. Through the use of technology that provides vehicle and shipment tracking, the freight transportation industry and other stakeholders can provide decision makers more detailed data and information on freight movements than was available in the past.

Figure 2 shows the distribution of freight volume on the entire freight transportation system—highway, rail, and inland waterways. The figure is based on data from different modal sources and represents 2002 data for rail and water and 2007 data for highway. The figure shows the segments of the network with high freight volumes that indicate potential locations of congestion. Clearly, all modes have locations where capacity could be limited compared to other locations in the respective networks.

In 2002, FHWA initiated the Freight Analysis Framework (FAF) to integrate disparate data sources to provide estimates of commodity flows, based on the origin and destination of freight movements. The original iteration of FAF, also known as FAF^1, was based on 1998 data and provided estimates for commodity flow volumes at the state, regional, and international levels for 2010 and 2020. FAF^2, the second generation, estimates 2002 volumes and values, provides forecasts through 2035, and is based on a host of public domain data sources. The FAF commodity origin destination database lays the foundation for transportation infrastructure analysis.

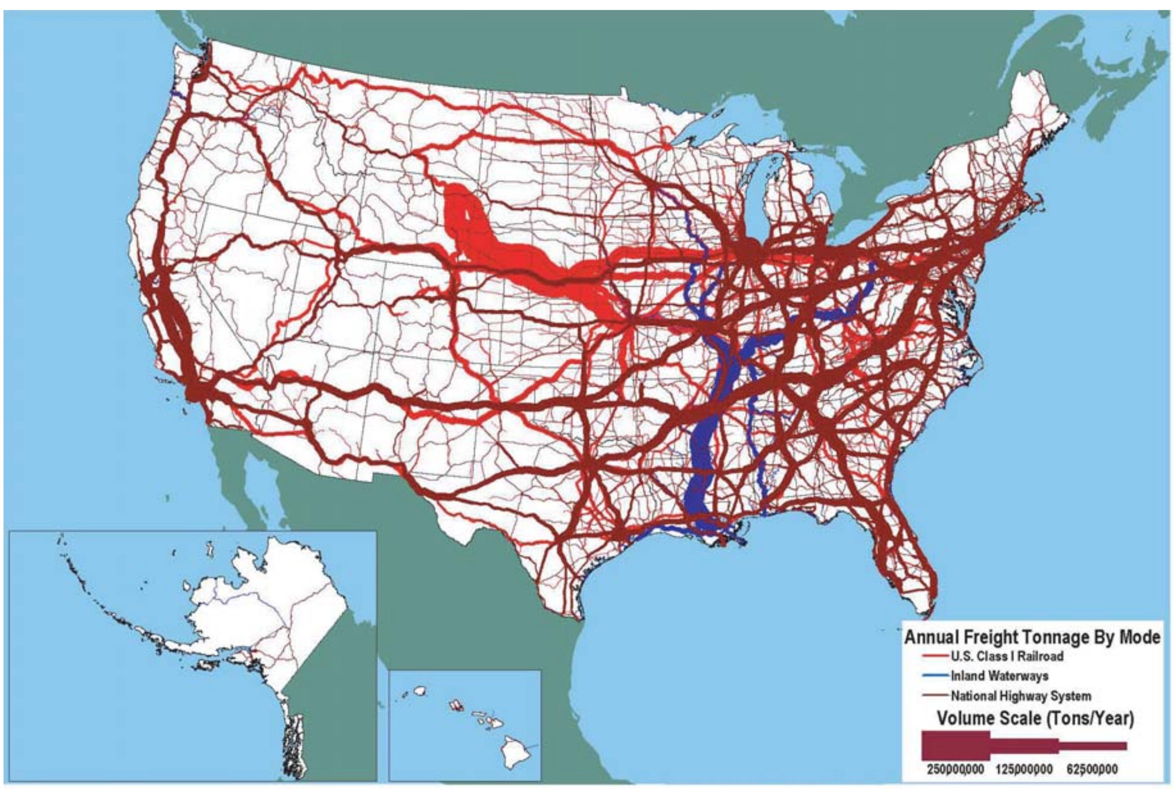
Table 1. Selected freight infrastructure statistics (*42–48*).

Modal Category	Length or Number
Highway	
Interstate Highway	47,344 miles
National Highway System (excluding interstates)	119,896 miles
Other Roads	3,849,257 miles
Rail	
Class I RRs	94,801 miles
Regional Freight Lines	16,703 miles
Local Freight Lines	28,415 miles
Deepwater Ports and Inland Waterways	
Navigable Waterway	26,000 miles
Public Ports (#)	150
Sea and River Ports (#)	230
Intermodal Terminals & Others	
Truck/Rail Terminals (#)	203
Oil Pipelines	64,336 miles
Gas Transmission	309,503 miles
Gas Distribution	1,079,565 miles
Airports	
Public Use Airports (#)	5,286

Table 2. Freight vehicles (*41*, *47*, *49*, *50*).

Vehicles by Mode	Number
Highway	
Combination Trucks	2,276,661
All Other Trucks	5,650,619
Rail	
Class I Locomotives	20,505
Class I Freight Cars	477,751
Other Freight Cars	691,329
Deepwater Ports and Inland Waterways	
Self-propelled Vessels	8,621
Barges (non-self-propelled)	32,381
Oceangoing ships[1]	426
Airports	
Air Carriers	8,194

[1] - U.S. flag vessels 1000 gross tons or more



Sources: Highways: U.S. Department of Transportation, Federal Highway Administration, Freight Analysis Framework, Version 2.2, 2007. Rail: Based on Surface Transportation Board, Annual Carload Waybill Sample and rail freight flow assignments done by Oak Ridge National Laboratory. Inland Waterways: U.S. Army Corps of Engineers (USACE), Annual Vessel Operating Activity and Lock Performance Monitoring System data, as processed for USACE by the Tennessee Valley Authority; and USACE Institute for Water Resources, Waterborne Foreign Trade Data, Water flow asssignments done by Oak Ridge National Laboratory.

Figure 2. Freight tonnage on freight transportation network (*51*).

Table 3. National summary of freight volumes (million tons) (*52*).

Mode	2002			2008			2035		
	Total	Domestic	Import & Export	Total	Domestic	Import & Export	Total	Domestic	Import & Export
Total	19,328	17,670	1,658	21,497	19,387	2,110	37,212	33,668	3,544
Truck	11,539	11,336	203	13,243	13,040	203	22,814	22,231	583
Rail	1,879	1,769	110	2,007	1,861	146	3,525	3,292	233
Water[1]	701	595	106	632	520	112	1,042	874	168
Air, air & truck	11	3	8	13	3	10	61	10	51
Intermodal	1,292	196	1,096	1,661	175	1,486	2,598	334	2,264
Pipeline & unknown	3,906	3,772	134	3,940	3,787	153	7,171	6,926	245

[1] - The numbers for water mode in the FAF database do not match totals in the waterborne commerce data programs (e.g., U.S. Army Corps of Engineers) because of differences in definitions and coverage.

In an attempt to make the FAF into a useful tool for measuring and analyzing the changing world of freight transportation, FHWA began developing annual provisional estimates of commodity movements including all modes of transportation starting with the year 2005. The goal is to provide practitioners in the areas of economic development and transportation planning with the latest updates to data on goods movement. Freight transportation providers can also use FAF in long-range planning efforts. The provisional estimates are developed based on publicly available freight data sources and methods that can be fully disclosed to the general public. Table 3 shows the 2002 FAF benchmark freight volumes in millions of tons by mode, the 2008 provisional estimates, and the 2035 forecasts. Note that the 2035 numbers have not been adjusted for the current economic recession. Table 4 shows the equivalent values in billions of U.S. dollars and Table 5 compares the average ton-miles.

A second major initiative, the FHWA-sponsored project titled "Freight Performance Measurement (FPM): Travel Time in Freight-Significant Corridors," is based on the use of wireless truck position data to measure truck speed and demand for roadways (*54*). This effort analyzes several million truck movements on Interstate Highway System (IHS) corridors throughout the United States and is intended to complement and provide real-time calibrations of the forecasts produced by FAF. Figure 3, an output of this project, shows the variation of the average speeds on selected major freight corridors across the United States. This figure illustrates the impacts of freight mobility constraints on average truck speed.

In 2008, the Transportation Research Board of the National Academies initiated project NCFRP-03, "Performance Measures for Freight Transportation" (*55*). This research makes an effort to develop a comprehensive set of performance measures to guide public policy decisions. The scope of these measures will include many aspects of the freight transportation system including:

- Freight system efficiency and effectiveness
- Infrastructure capacity and condition
- Safety and security
- Energy use and the environment.

The outcomes of these initiatives are expected to provide decision makers with a basis for identifying and evaluating potential solutions to freight mobility constraints and provide benefits to both motor carriers and the general public.

Table 4. National summary of freight values (billion dollars) (*52*).

Mode	2002			2008			2035		
	Total	Domestic	Import & Export	Total	Domestic	Import & Export	Total	Domestic	Import & Export
Total	13,228	11,083	2,145	16,767	14,217	2,550	41,869	29,592	12,277
Truck	8,856	8,447	409	11,194	10,719	475	23,768	21,655	2,113
Rail	382	288	94	466	352	114	702	483	219
Water	102	76	26	44	27	17	152	103	49
Air, air & truck	771	162	609	1,022	206	816	5,924	721	5,203
Intermodal	1,967	983	984	1,881	779	1,102	8,966	4,315	4,651
Pipeline & unknown	1,150	1,127	23	2,161	2,134	27	2,357	2,315	42

Table 5. National summary of freight ton-miles (billions) (*52, 53*).

Mode	2002			2008			2035		
	Total	Domestic	Import & Export	Total	Domestic	Import & Export	Total	Domestic	Import & Export
Total	4,432	4,161	271	4,749	4,419	330	8,220	7,648	572
Truck	1,246	1,224	22	1,392	1,370	22	2,463	2,400	63
Rail	1,605	1,511	94	1,735	1,600	135	3,012	2,813	199
Water	612	519	93	602	502	100	909	763	146
Air, air & truck	14	4	10	17	5	12	77	13	64
Intermodal	23	4	20	27	3	24	47	6	41
Pipeline & unknown	932	900	32	977	939	38	1,712	1,653	59

3.4 Highways

Infrastructure: The most recent version of the National Highway Planning Network (NHPN) represents more than 525,000 miles of public roadways including the IHS, National Highway System (NHS), National Network (NN), and other state highways. The NHS represents about 31 percent of the entire public highway network and the 47,344 miles of Interstate highways represent about 28 percent of the NHS (*42*). It has been noted that the growth in overall traffic and growth in freight in particular have outpaced the expansion of the transportation system. Between 1980 and 2003, lane-miles of highways increased 5 percent while vehicle miles of travel increased 89 percent (*57*). The ability of the freight transportation system to support increasing capacity demand remains a challenge.

Capacity: To examine the ability of the highway network to meet current and future freight demand, capacity analysis

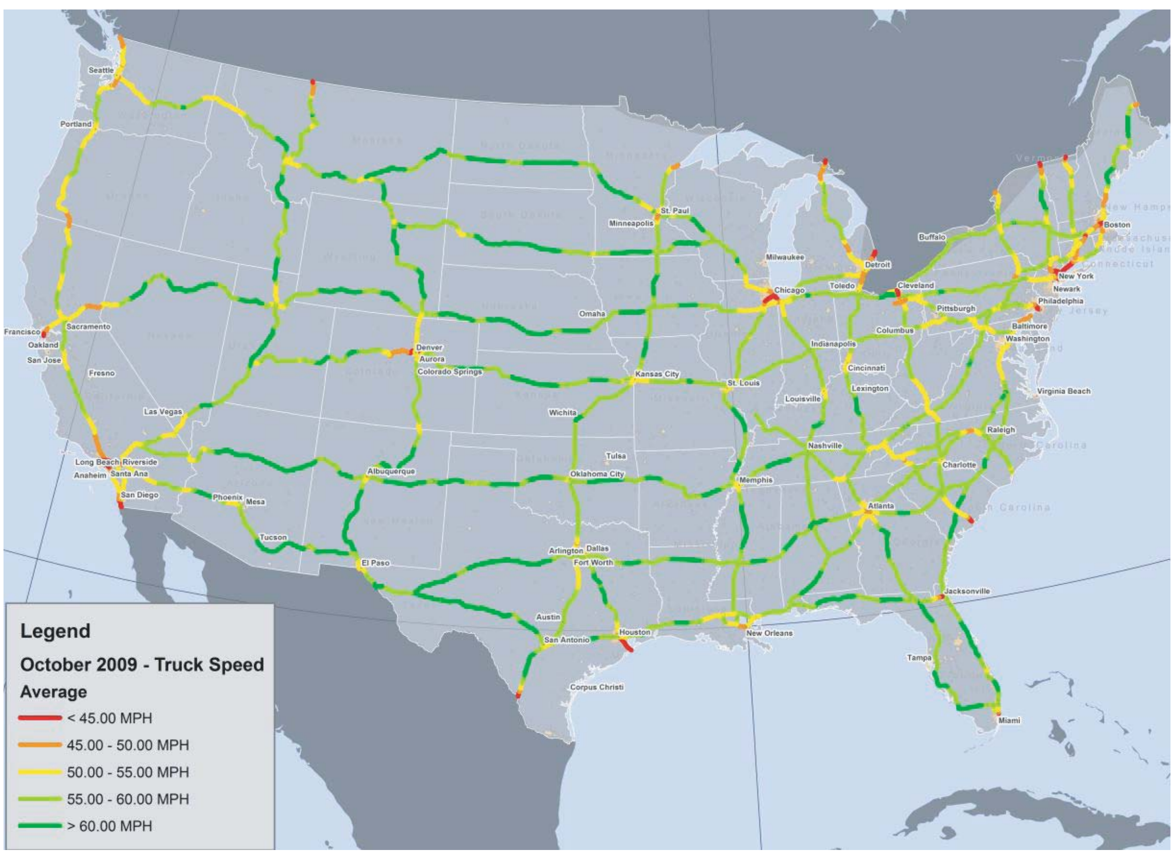


Figure 3. Average truck speeds on selected Interstate highways, 2009 (56).

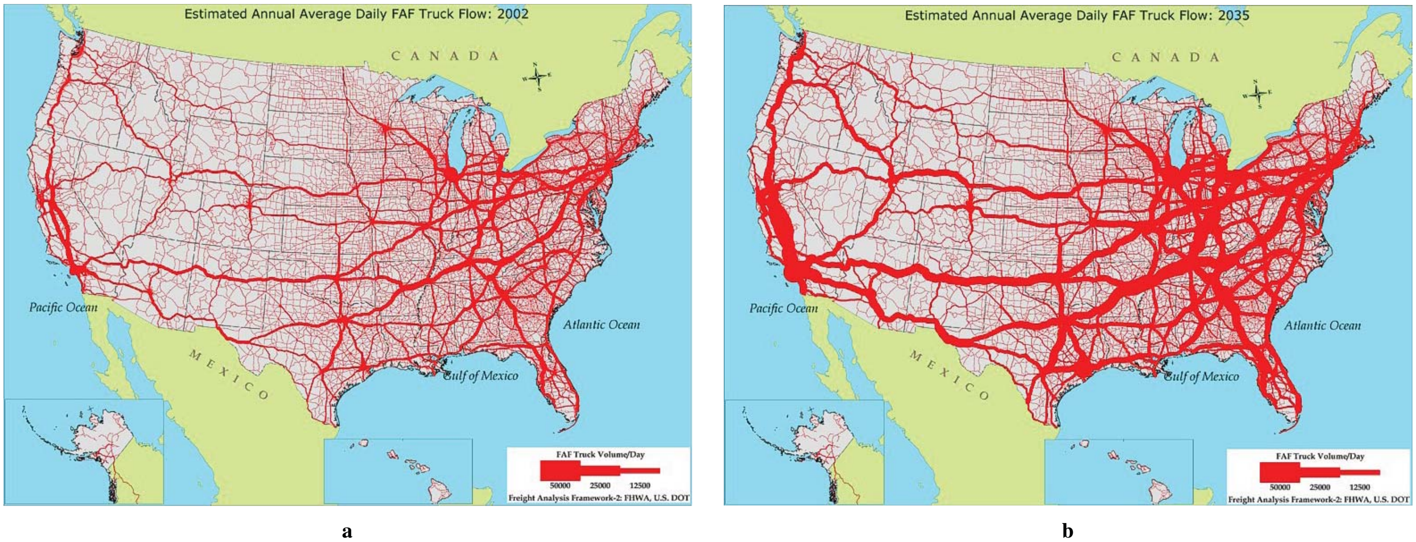


Figure 4. Truck flow on FAF² highway network (a) base year 2002 and (b) 2035 (58).

was conducted using the FAF² origin-destination (O-D) data. Figure 4 shows the truck traffic volumes on the freight transportation network for the 2002 base year and the forecast for 2035, respectively. The highway capacity impacts of the 2002 and 2035 freight truck traffic volumes are also shown in Figure 5. This figure illustrates highway congestion for 2002 and 2035. The impacts on highway capacity are expressed as the miles of highway that fall into one of the three categories based on the volume/capacity (v/c) ratios:

1. Below capacity—v/c less than 0.75 (green)
2. Approaching capacity—v/c ratio 0.75 to 1.0 (amber)
3. Exceeding capacity—v/c ratio greater than 1.0 (red) (*58*).

Figure 6 shows the percentage of miles exceeding the capacity in the years 2002 and 2035. The following observations can be made:

- About 3 percent of NHS miles exceeded the capacity in 2002, and this is estimated to increase to about 26 percent in 2035.
- In 2002, 320 miles of rural Interstate exceeded the capacity, and the miles with heavy congestion are expected to increase to 9,442 miles in 2035, which represents 30 percent of the total rural Interstate miles.
- About 2,904 miles of urban Interstate were heavily congested in 2002, accounting for 18 percent of the total NHS

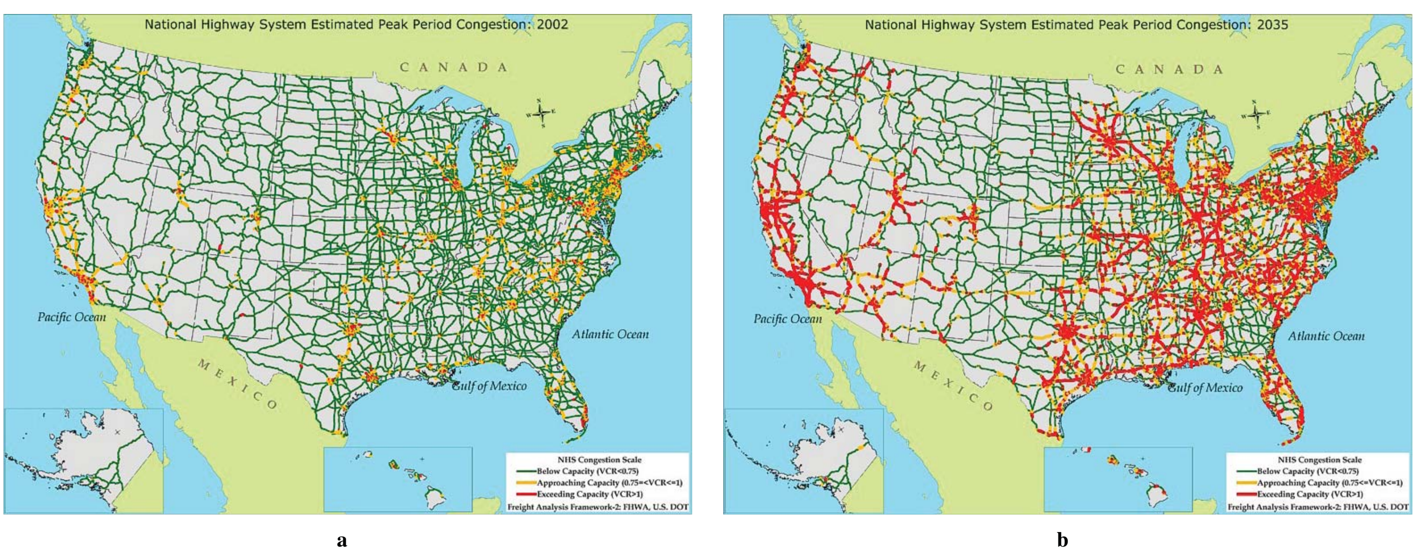


Figure 5. NHS highway network congestion (a) base year 2002 and (b) 2035 (58).

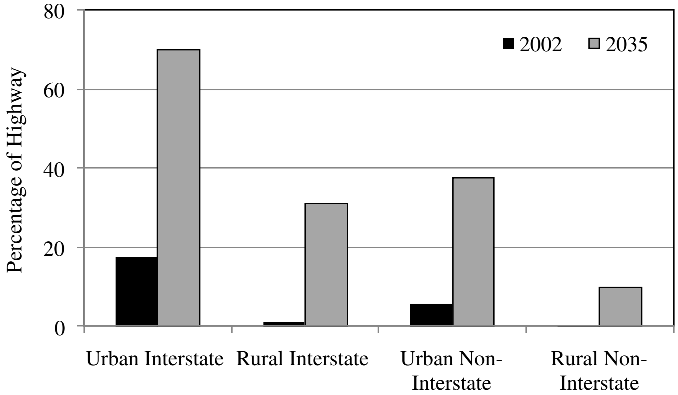


Figure 6. Percentage of NHS highway miles exceeding capacity (58).

urban Interstate miles. This percentage increases considerably to 70 percent in 2035, corresponding to 11,534 miles of urban Interstate that will exceed the capacity.

To illustrate the distribution of truck traffic on the highway network for the years 2002 and 2035, truck volume groups used are:

1. Light Truck Traffic—0 to 5,000 Annual Average Daily Truck Traffic (AADTT)
2. Moderate Truck Traffic—5,000 to 10,000 AADTT
3. Heavy Truck Traffic—greater than 10,000 AADTT.

Figure 7 shows the percentages of highway miles carrying different levels of truck traffic. It is noted that:

- Over 82 percent and 66 percent of the NHS miles in the years 2002 and 2035, respectively, carry less than 5,000 AADTT.

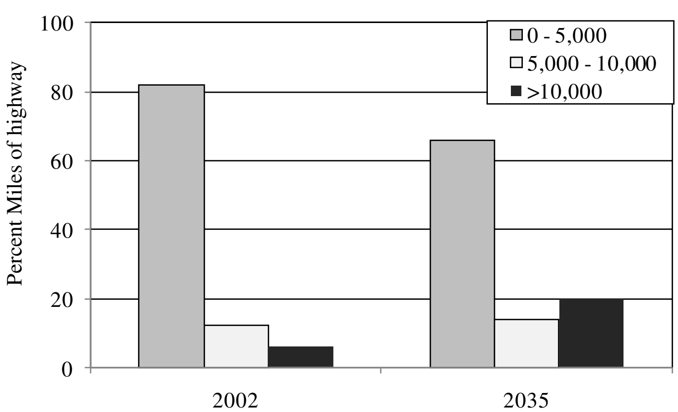


Figure 7. Percentage of NHS highway miles and truck volume (58).

- In 2002, 5,882 miles or 36 percent of urban NHS Interstate and 3,448 miles or 11 percent of rural NHS Interstate carry more than 10,000 trucks per day. The miles with heavy truck traffic will increase more than twofold in 2035 to 11,855 miles or 72 percent of urban NHS Interstate and 15,353 miles or 51 percent of rural NHS Interstate.
- In 2002, only 6 percent of the 162,164 NHS miles experience truck traffic in excess of 10,000 trucks per day. This percentage is estimated to rise to 20 percent in 2035.

Industry Segments: The trucking industry is also the most complex and diverse mode ranging from owner-operators with one truck to very large fleets with more than 15,000 tractors. In the United States, nearly 97 percent of trucking companies operate less than 20 trucks, although medium and large carriers haul the majority of freight and employ the majority of drivers (*57*). Motor carriers may be either private carriers, dedicated to hauling intracompany freight only, or for-hire carriers that haul goods for third parties. In 2005, the following types of motor carriers were operating in the United States:

- 290,629 for-hire carriers
- 504,166 private carriers
- 234,892 "other" interstate carriers.

Major segments within the industry include truckload (TL), less-than-truckload (LTL), and specialized. Specialized carriers may include overweight/oversize carriers, bulk liquid carriers, and flatbed carriers. Mobility constraints affect segments of the industry in different capacities. For example, TL carriers operating in many jurisdictions may be most affected by the lack of a centralized clearinghouse of road system status. Conversely, the mobility of LTL carriers may be most impacted by inadequate access to retail establishments or traffic signal timing geared toward automobiles. Lastly, specialized hazardous materials (hazmat) carrier operations may be most impacted by hazmat route restrictions or hazmat-related delays at intermodal facilities. The distribution of carriers in the United States includes:

- TL (52 percent)
- LTL (24 percent)
- Specialized, bulk/tank (5 percent)
- Other specialized (19 percent) (*49*).

Truck Vehicle Types: There are two main types of trucks: single-unit or straight trucks and combination trucks. In 2006, there were 26.9 million straight and combination trucks registered for business purposes in the United States (*57*). Commercial motor vehicles are further grouped by gross vehicle weight (GVW) into eight truck classes. Classes 1 through 3 are vehicles up to 14,000 GVW, Classes 4–6 weigh up to 26,000 GVW, and Classes 7–8 are vehicles that weigh more than 26,000 GVW. From 2000–2006, vehicle sales for these truck classes increased as follows:

- Classes 1–3: 14 percent to 8.7 million vehicles
- Classes 4–6: 33 percent to 170,000 vehicles
- Classes 7–8: 12 percent to 375,000 vehicles (*49*).

Human Resources: Trucking is a major employer across all segments of the economy. The industry provided one in thirteen private-sector jobs for 8.7 million people in 2005, a 1.2 percent increase over 2004 (*52*). Of these employees, 3.5 million people are professional truck drivers. Truck driver job functions vary significantly across the industry. For example, long-haul truckload drivers may be away from home for weeks at a time and travel in predominantly rural areas. Conversely, LTL pickup and delivery drivers may travel primarily in urban areas within 100 miles of their home terminal. Despite significant differences in operating characteristics, the industry as a whole faces systemic operating challenges.

The industry continues to face both a shortage of drivers and difficulty retaining drivers. The need for truck drivers is expected to increase by 19 percent between 2002 and 2012, outpacing the 14.8 percent expected increase in overall job growth (*59*). Projections suggest the driver shortage could rise to 111,000 by 2014 as 320,000 new drivers will be needed to keep pace with growth in freight volumes while another 219,000 drivers will be needed to replace drivers that either retire or leave the industry. This translates to a need for more than 54,000 new drivers per year over the next decade.

Among the highlights are the following significant distributions of freight upon the system:

- NHS is only 4 percent of all mileage but it transports an estimated 75 percent of all truck freight, inclusive of IHS (*49*).
- The IHS composes 1 percent of all highway mileage but transports an estimated 43 percent of all truck freight (*49*).
- FHWA estimates that the percentage of urban Interstate sections carrying more than 10,000 trucks per day will increase from 27 percent in 1998 to 69 percent in 2020.
- Approximately 53 percent of urban Interstate mileage will likely be congested in 2020 in comparison to about 20 percent today.

Performance: Although trucking is the dominant mode, the nation's logistics rely on the interconnected and interdependent nature of the various modes. Trucking is dominant on higher value, shorter distance trips. Trucking is also the dominant mode in terms of miles traveled, value of freight, and volume of freight. The value of a ton shipped by air and truck is $88,618; by truck and rail, $4,892; by truck alone, $775; by water, $401, and by rail alone, $198 (*1*). This interconnectivity of each mode can belie the importance of the mode, if it is only viewed by its share of weight or value. Although water shipments may represent only 5.2 percent of all shipments by value, they are indispensible in moving heavy, raw commodities such as chemicals, grain, and petroleum. Air freight is a small fraction of all shipments by tonnage but is essential for critically high-value freight such as electronics, or even fresh seafood. The relatively high value of the truck-rail intermodal shipments at nearly $5,000 per ton illustrates the value-added nature of intermodal freight transportation's ability to ship high-value goods long distances in a rapid, reliable manner. Therefore, each mode has evolved to serve an irreplaceable niche in the interconnected transcontinental freight network.

The trucking industry is the largest sector of freight movement, carrying approximately 69 percent of all freight tonnage, totaling 10.7 billion tons of freight and 83.8 percent of freight transportation revenue (*57*). According to a recent report (*1*), the nation's freight ton-miles by all freight modes increased steadily at an average rate of 1.2 percent per year between 1980 and 2004. Between 2002 and 2008, the volume of domestic freight movements by truck increased by 15 percent. In 2008, trucks carried 75 percent or $10.7 trillion of total value of domestic freight (and 64 percent of all freight value) representing an increase of 27 percent above the 2002 values. Between 1980 and 2002, the number of freight trucks increased by 37 percent (i.e., from 5.8 million in 1980 to 6.2 million in 1990 to 7.9 million in 2002). Average annual distance traveled by commercial trucks also increased from 19,000 miles per truck in 1980 to 27,000 miles per truck in 2002.

The growth in U.S. freight volume places pressure on the transportation system arising from congestion, delays, capacity management, and operational bottlenecks, and it impacts individual modes as well as multimodal freight movements. The consequence of increases in VMT is increased delay resulting from congestion, which affects the productivity of trucking. The impacts of congestion on trucking can also be measured in terms of value-of-time and vehicle operating cost savings resulting from more efficient and reliable operating speeds on the highway system.

According to the 2008 updates to the FAF commodity O-D database, Table 6 shows the top five commodities for domestic movements by trucks in terms of tonnage and value.

Vehicle Miles Traveled: According to FHWA, in 2005 commercial trucks traveled an average of 13.7 percent of total rural VMT and 7.1 percent of total urban VMT (*11*). According to an analysis by Martin Labbe Associates for the American Trucking Associations (ATA), Class 8 trucks traveled a total of 130.5 billion miles in 2005, an average of 45,000 miles per truck (*57*).

Table 6. Top five commodities moved by truck in 2008 (*52*).

Rank	In Terms of Tonnage	In Terms of Value
1	Gravel	Machinery
2	Nonmetal mineral products	Mixed freight
3	Cereal grains	Motorized vehicles
4	Waste/scrap	Electronics
5	Gasoline	Textiles/leather

Table 7. Scale of rail operations.

Class	Number	Route-Miles	Employees	Revenue (Billion $)
Class I	7	94,801	167,581	50.3
Regional	33	16,713	7,742	1.7
Local	519	28,415	11,634	2.0
Total (USA)	559	139,929	186,957	54.0
Canadian	2	561	-	-
Total	561	140,490	186,957	54.0

From 1999 to 2004, annual truck VMT for all classes of trucks grew at an average rate of 3 percent year to year. However, in 2005 truck VMT declined 8.1 percent to 287.2 billion miles (*1*). The cause of declining truck VMT may be related to increases in congestion, changes in operating schema, 1000-mile trip conversions to intermodalism, or some combination of these factors. As VMT growth and increases in commercial motor vehicle registrations likely will continue to outpace infrastructure investment increases, the need for low-cost and quickly implementable solutions will also grow. Improvements in freight flows likely improve all vehicle flows; reducing operational impediments can lower business costs, in turn reducing both unit prices for the consumer and inflationary pressures for the economy.

3.5 Railroads

Railroad Industry Ownership Profile: Ownership of railroads is almost exclusively private, and the existing industry is the result of hundreds of company mergers over the last century and a half. The most important exception to private ownership is the Alaska Railroad, a state-owned operation since it was purchased for $22.3 million and transferred from the Federal government in 1985. Other states and municipalities own segments of railroads leased to private operators or joint terminal companies. Amtrak is not a freight railroad, but operates its passenger service on tracks owned by freight railroads (except in the Northeast Corridor and a track segment in Michigan it owns outright).

Physical Infrastructure: Rail infrastructure consists of track and structures, yards, locomotives, cars, and signals. The rail network has shrunk considerably, from 254,000 miles of Class I railroads in 1916 to 140,810 miles in 2006. Classification of railroads is historically by size and Table 7 shows the breakdown by ownership of the rail network, number of employees, and revenue. Currently there are 559 railroads operating in the United States consisting of 7 Class I railroads, 33 regional carriers, and 519 local railroads. In addition, two Canadian Railroads have U.S. operations large enough to qualify as Class I if they were separate entities under U.S. corporate status. According to the Federal Railway Administration (FRA), Class I railroads represent only 1 percent of the railroad companies, own 72 percent of the network of railroads in the country, and generate more than 90 percent of the rail revenue (*47*). The Class I railroads also own 36 percent of all freight cars. A recent study conducted by the Association of American Railroads (AAR) (*60*) concludes that the railroads' current network is reaching its capacity and that rail congestion will occur if the system is not expanded.

Railroad capacity is determined by many factors including the amount of railroad track and rolling stock, the number and power of locomotives, maintenance, staffing levels, and a wide variety of operating strategies (*4*). There is currently a great deal of interest in railroad capacity now and in the future. Several factors explain the interest:

- Traffic growth, both observed and forecast, raises the question of whether railroads will have adequate capacity to enable continued handling of the growing business.
- Tightening of capacity in 2007–2008 has made it possible for railroads to increase freight rates. (When there is excess capacity, railroads historically have lowered rates in the attempt to attract business; when there is a shortage of capacity, rates rise to balance supply and demand.)
- Given that rail is 2 to 2.5 times more fuel efficient than trucks (*61*), and because highways are increasingly congested, many policymakers want to encourage the shift of some truck traffic onto railroads—which is more likely if railroads have adequate capacity and can meet needed service levels.
- Advocates of increased rail passenger service understand that availability of rail track capacity is a critical issue for expansion of passenger services.
- Rail freight is often assumed to have other benefits, including environmental (lower emissions per ton-mile), an excellent safety record, low-cost rate levels for bulk goods, and movement of hazardous materials on private right-of-way (i.e., not mixed in with cars and trucks on the highway system).

Investment: As private enterprises operating both owned equipment and infrastructure, American railroads must raise

Table 8. Freight car ownership.

Types of Freight Cars	Class I	Private Cars	Regional and Local	Totals
Box Cars	76,066	15,008	41,034	132,108
Covered Hoppers	114,100	270,145	20,517	404,762
Flat Cars	95,083	52,528	21,724	169,335
Refrigerated	19,017	-	2,414	21,431
Gondolas	99,837	82,544	21,724	204,105
Hoppers	71,312	75,040	12,069	158,421
Tank Cars	-	255,137	-	255,137
Totals	475,415	750,402	119,482	1,345,299

large amounts of capital and reinvest in operations and capacity. In 2006, industry capital investments were close to $8.5 billion—over 16 percent of operating revenues. Few major industries reinvest at this rate. Included in capital expenditures are purchase and major overhaul of locomotives; railroads have nearly 24,000 locomotives in service. The industry has access to over 1.3 million freight cars; this figure includes freight cars owned by railroads large and small, leasing companies, and shippers. Table 8 shows the distribution of ownership by type of freight car.

Reinvestment by the private enterprise railroads is a function of their ability to earn revenues in excess of their cost of conducting business. The fundamental purpose of rail deregulation in the 1970s was to enable the railroads to behave like other businesses in the American private enterprise system, that is, to earn revenues adequate to keep existing capital in the industry and to attract new investment for expansion and facilities rehabilitation. After the collapse of the Penn Central and other bankrupt companies in the early 1970s, the Federal government took responsibility for reorganizing rail service in the Northeast. The planning process resulted in abandonment of thousands of rail route-miles and government expenditures of some $8 billion to acquire, rehabilitate, and cover operating losses for its new creation, Conrail. Until the Staggers Act was passed in 1980, however, Conrail continued to lose about $1 million/day. Since the Staggers Act, railroads have made a remarkable renaissance (see Figure 8). Conrail was sold to the public in an initial public offering (IPO) in 1987, and in 1998–1999 was divided between Norfolk Southern (~ 60 percent) and CSX Corporation (~ 40 percent). The large Class I railroads are now earning close to their cost of capital and are able to support their huge investment requirements from retained earnings.

Human Resources: Railroads have reduced employment dramatically, which is a key source of productivity improvement in the industry. One major factor in reducing employment was the *Presidential Emergency Board 219* finding of 1991

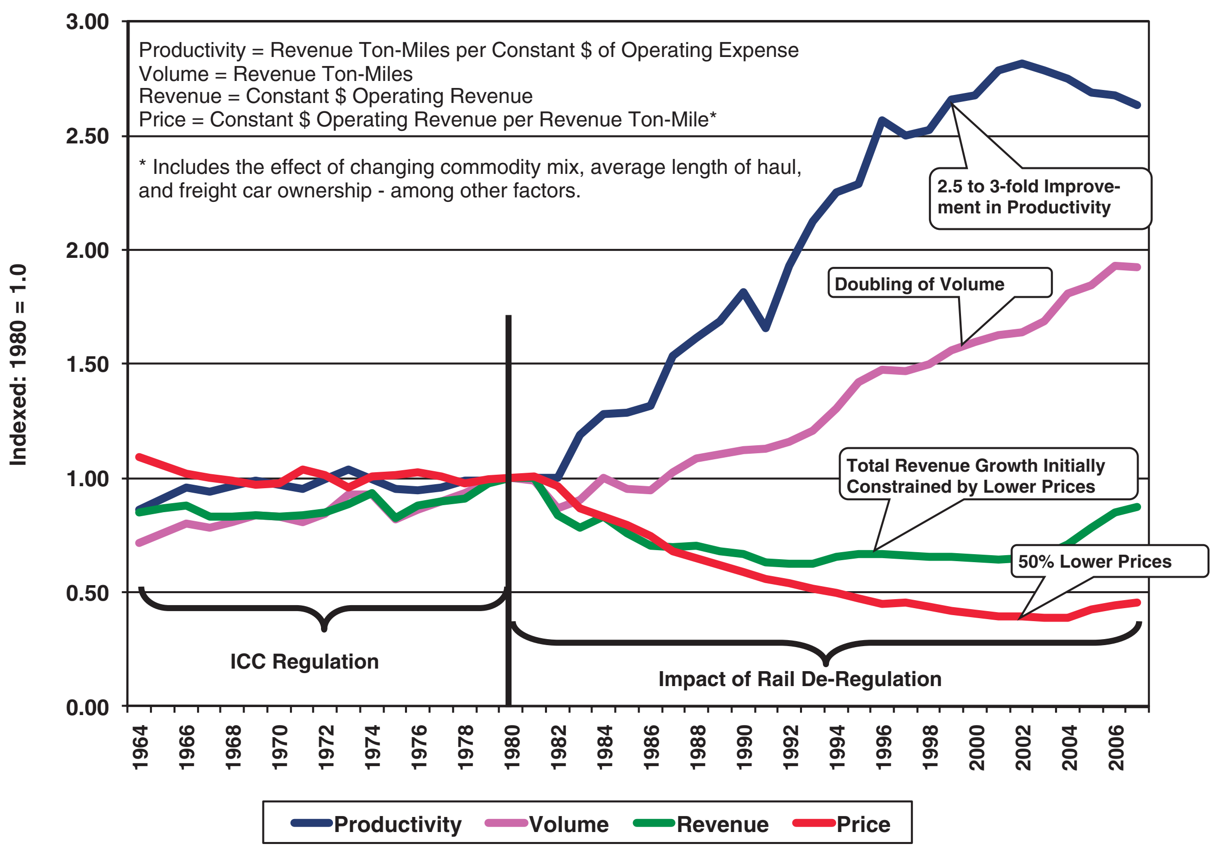


Figure 8. Performance of the American railroad post-Staggers Act of 1980 (62).

Table 9. Employment and wages (*63*).

Employees	1980 Benchmark	2005	2006
Employees—all RRs (000)	532	232	237
Class I (000)	458	162	168
Wages / Year Class I ($)	$ 24,695	$ 66,975	$ 68,141

(after threatened strikes and lock-outs) that facilitated reduction of standard train crews from four to two if only limited switching would be needed en route. Railroads are heavily unionized, and both wages and working conditions are usually defined in contracts between individual railroads and their employees' bargaining units. There has been a significant reduction in the number of bargaining units in recent years. Today, the United Transportation Union and the Brotherhood of Locomotive Engineers are the largest rail unions, but other industry workers are represented by a significant number of other labor unions. Table 9 summarizes wage and employment data for the industry.

These trends indicate that:

- The Class I railroads are only 7 out of more than 500 U.S. railroads but they handle 93 percent of rail freight in the United States (*45*).
- Major U.S. rail corridors will require additional rail capacity and right-of-way.
- Railroads will be seeking to optimize their capacity through new technology.
- The railroads face a continuing capital shortage despite their growth.
- Partnering with public agencies on major corridor projects will become more valuable to the railroad and the public.

Performance: Railroads have often been described as the nation's first big business. They are unique or remarkable in other respects as well. If measured by ton-miles (the statistic measuring a movement of a ton of goods 1 mile) railroads are the largest general freight mode in the United States. According to the U.S. Congressional Budget Office (CBO) (*64*), railroads moved 47 percent of intercity freight measured in ton-miles and 30 percent measured in terms of tons; this figure excludes air freight and pipelines. Motor carriers originate more tons of freight and earn more revenues than railroads by a considerable margin, but railroads have long average hauls and carry many heavy, bulky commodities of lower value per pound. For reasons such as this, average fare levels (prices) are considerably lower than is the case for motor carriers. Table 10 characterizes train lengths, average tonnage, and average lengths of haul over the past 50 years.

FRA reports that in 2006, the railroads generated $54 billion in revenue and set a new record for freight traffic with 1.77 trillion revenue ton-miles, up 4 percent from 2005. However, these accomplishments are relatively recent and are the result of decades of struggle, retrenchment, bankruptcies, deregulation, and slow rebirth of the American rail industry. In 1920, the American rail industry was the largest U.S. employer with two million workers (*65*) compared to 187,000 in 2006. Although the current American rail network is 44 percent smaller in terms of miles, America's freight railroads generated 93 percent more ton-miles of freight in 2006 than they did in 1980, and they did so with 32 percent fewer route-miles, 63 percent fewer employees, 16 percent fewer locomotives, and just 7 percent more gallons of diesel fuel (*60*). Increases in rail productivity in the two decades indicate increased utilization of railroad infrastructure through technological innovation and improved operations (*4*).

These trends have resulted in the railroads operating fewer tracks but having much higher train volumes. Train lengths have also increased, so that it is common to see trains up to 2 miles in length. The AAR reports that between 1980 and 2006 freight volumes, profitability, and on-time performance

Table 10. Trends in train and freight car productivity (*4*).

Year	Average Cars per Train	Average Tons per Train	Average Tons per Carload	Average Length of Haul (miles)	Productivity per Carload (ton-miles)
1955	65.5	1,359	42.4	447	19,035
1960	69.6	1,453	44.4	461	20,522
1965	69.6	1,685	48.9	503	24,621
1970	70	1,821	54.9	515	28,311
1975	68.6	1,938	60.8	541	32,894
1980	68.3	2,222	67.1	616	41,352
1985	71.8	2,574	67.7	665	44,971
1990	68.9	2,755	66.6	726	48,313
1995	66.3	2,870	65.3	843	55,032
2000	68.6	2,923	62.6	843	52,803
2005	68.9	3,115	61	894	54,473
% change	5.2	129.2	43.9	100.1	186.2

have significantly increased, coinciding with deregulation under the Staggers Act of 1980. At the same time, rail employee productivity rose 427 percent, locomotive productivity rose 128 percent, and productivity of each mile operated rose 185 percent. Overall productivity measured in ton-miles per dollar of inflation-adjusted operating expenses also rose 167 percent since deregulation (*60*).

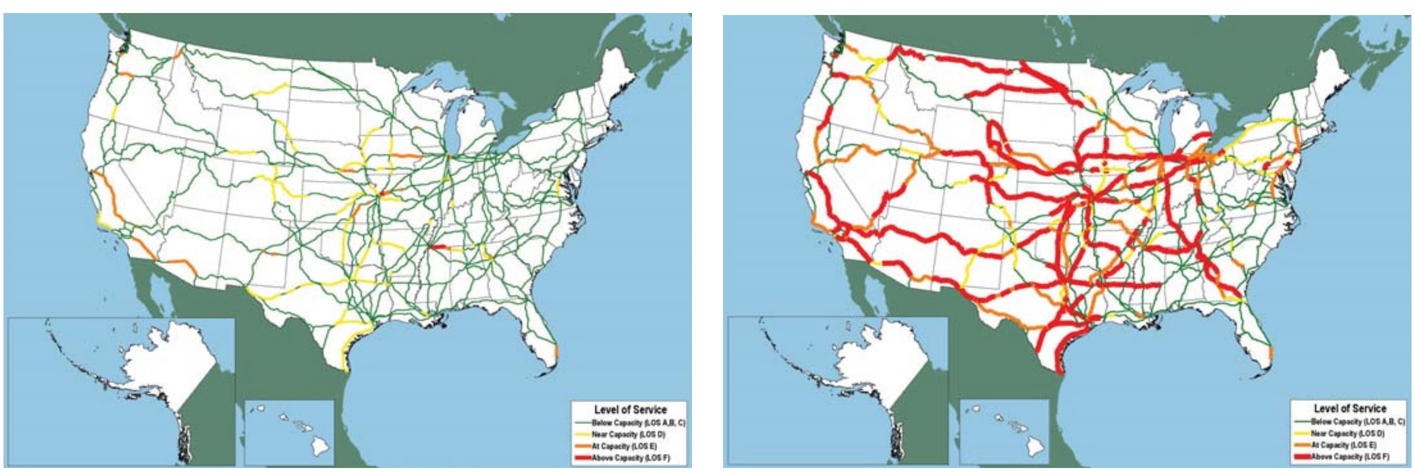
These successes have made railroads profitable, but they still struggle to earn their cost of capital as railroads earn only about 7 percent on net capital, according to FRA (*47*). For decades, American railroads earned the lowest rates of return of any major U.S. industry. Between 1960 and 1979, the average annual return on shareholder equity was 2.3 percent (*65*). U.S. railroads have estimated that up to 40 percent of their revenues are devoted to capital assets, a percentage which is significantly higher than most industries. The high cost of maintenance for track, rolling stock, and yards requires substantial capital investments, which are not liquid or mobile. Investing in a line represents a significant long-term investment for a railroad. Railroads' reluctance to invest in or cost-share on projects has also been constrained by the intense competitive pressures they face for rates. Because railroads compete with barges and trucks, they have not raised rates commensurate with inflation.

Furthermore, deregulation and related changes (easier abandonments, transfer of passenger services to Amtrak and commuter agencies, Northeast reorganization of bankrupt railroads, etc.) enabled ending many inefficient operations. Rate deregulation allowed "pricing away" (de-marketing) unprofitable traffic, closing junctions, and changing divisions, among other actions. Dennis (*66*) examined the relative importance of the various factors that may underlie the decline in railroad rates since the Staggers Act. Factors noted to contribute to the decline in rates include changes in commodity (e.g., increasing percentage of bulk commodities), increased length of haul, and increased private ownership of equipment. The productivity gains resulting from deregulation could be attributed to deployment of technology and more efficient operations. Spychalski and Swan (*67*) also observed that the dramatic change in the structure of the U.S. rail freight industry since economic deregulation was accompanied by the concentration of the Class I rail industry and a subsequent, significant decline in rates. Boyer (*68*) also showed that modal shifts between truck and rail were relatively minor because the relative prices did not change. In other words, changes in traffic for a given mode could be attributed to induced demand rather than to modal shifts.

The USDOT's FAF^2 estimated that domestic freight movements by rail between 2002 and 2008 increased by about 5 percent, whereas exports have increased by about 90 percent and imports increased by only 8 percent (*52*). This increasing demand is spurred by general growth in the economy and increasing foreign trade. This presents an increase in total tonnage of freight moved by rail from 1.8 trillion tons in 2002 to 2.0 trillion tons in 2008. This growth is forecast to increase to 3.5 trillion tons by 2035. During the same period, the value of exports increased by over 63 percent and the value of imports increased by 7 percent (*52*).

Figure 9a shows the 2007 train volumes compared to the 2007 capacity and Figure 9b shows the 2035 estimated train volumes compared to 2007 capacity. This assumes that capacity of the rail freight remains unchanged. The figures show locations with severe capacity problems.

Railroads carry a broad range of commodities, with vastly different shipping characteristics, intrinsic value, and geo-



a b

Note: Level of Service (LOS) A through F approximates the conditions described in Transportation Research Board, *Highway Capacity Manual 2000*.

Figure 9. Performance of freight rail system (a) 2007 and (b) 2035 (26).

Table 11. Commodities and types of freight cars.

Commodity Characteristics	Types of Commodities	Types of Freight Cars
Bulk Dry Cargo, Uncovered	Coal, Sand & Gravel	Hoppers, Gondolas
Bulk Liquid Cargo	Chemicals, Ethanol HFCS	Tank Car
Pressurized Gas	Toxic Hazardous Materials, Propane	Pressurized Tank Car
Bulk Dry Cargo, Covered	Grain, Soda Ash, Some Fertilization	Covered Hoppers
Manufactured Goods, Protected	Autos—Setup, Auto Parts, Some Foods, Newsprint, Paper	Box Cars, Auto-Rack
Manufactured Goods, Uncovered	Pipe, Agricultural Equipment, Some Building Products	Flat Cars, Gondolas, Center Beam Flats
Refrigerated	Frozen Food, Fresh Fruits or Vegetables	Refrigerated Box Cars
Containerized Goods	Imported Goods	Container Flat Cars
Trailers on Flat Cars	Domestic Goods	Trailer Flat Cars

graphic networks or markets. In this sense, railroads are the most complex mode of transport. Major categories of commodities captive to rail include coal, chemicals, farm products, and transportation equipment. According to the AAR, mixed shipments, which include intermodal shipments, have recently become the largest single revenue category (*60*). Table 11 describes the range of commodity groups and railcar equipment types used by railroads for moving freight.

Table 12 shows the top five commodities moved by rail in terms of tonnage and value. These are derived from the 2008 updates to the FAF commodity O-D database for domestic movements.

3.6 Intermodal

Intermodal shipments inherently rely on two or more modes, typically rail and truck, rail and ship, or truck and air, and are generally time-sensitive commodities. Intermodal connectors are critical elements of an integrated freight transportation system. According to FHWA's *NHS Intermodal Freight Connectors* (*44*), there are 517 freight-only terminals on the NHS, which include 253 ports (ocean and river), 203 truck/rail terminals, and 61 pipeline/truck terminals. In addition to these freight-only terminals, 99 major freight airports, which handle both passengers and freight, were included in the list of NHS connectors that were inventoried. These 616 intermodal freight terminals represent 1,222 miles of NHS connectors. NHS connectors are short, averaging less than 2 miles in length. The most recent version of the NHPN identified 1,323 connectors on the NHS, which includes both passenger and freight intermodal connectors. Traffic volume on these connectors ranges between 100 and 110,000 vehicles per day.

NHS Intermodal Freight Connectors (*44*) noted that nearly one-third of total connector miles were judged to be in need of additional capacity. Approximately 38 percent of connector miles needed pavement work, which includes resurfacing and reconstruction of lanes and shoulders. The most frequently cited deficiencies of the intermodal connectors were problems with shoulders, inadequate turning radii, and inadequate lane width. Connectors to ports have twice the percentage of mileage with pavement deficiencies when compared to non-Interstate routes. Connectors to rail terminals had 50 percent more mileage in the deficient category. Connectors to airport and pipeline terminals appeared to be in better condition with about the same percentage of mileage with pavement deficiencies as those on non-Interstate NHS routes. This may be due to the higher priority given to airport access because of the high volume of passenger travel on these roads.

Intermodal shipments from the coasts into the heartland have been predicted to at least double in the coming decades. Prior to 2008, the booming trade with China, the growth in India, and the general global economic trade expansion portended significant expansion in the rail intermodal shipments. Panama is expanding the Panama Canal, which will allow the largest Asian container ships increased access directly to the East Coast and Gulf of Mexico ports. Such trends could significantly increase intermodal traffic on the eastern and southern U.S. coasts, as has already occurred on the West Coast. On the

Table 12. Top five commodities moved by rail (2008) (*52*).

Rank	In Terms of Tonnage	In Terms of Value
1	Coal	Motorized vehicles
2	Cereal grains	Coal
3	Metallic ores	Plastics/rubber
4	Fertilizers	Basic chemicals
5	Basic chemicals	Base metals

East Coast, the Port of Norfolk, Virginia, has aggressively been upgrading the facility to handle larger intermodal ships.

Measuring the performance of intermodal facilities is key to understanding possible improvements to productivity and efficiency at such locations. Intermodal facility performance measures can be placed into two categories: those measures related to movement to or from a facility and those related to goods movement between modes (*44*).

In the first category, FHWA (*44*) suggests that the conditions on the connector roadways between the NHS and the intermodal facility should be measured. Such measures might include average travel time between the facility and the NHS, average travel rates along the connector (this would include an average of all hours, as well as breakouts by time of day, peak vs. non-peak, weekend vs. weekday, etc.), the reliability of movement on connectors, and total hours of delay experienced on a connector.

The second category, which focuses on the measurement of activity within an intermodal facility, is referred to by FHWA as "freight transfer time between modes" (*44*). Examples include:

- Transfer time
- Wait times/queuing at facilities
- Turning radius or mobility within facility (which is related to delay and transfer times)
- Volume-to-capacity ratios within a facility (including capacity measures specific to railroad, truck, ship, or air) (*69*).

Table 13 shows the top five commodities moved by multiple modes (intermodal) in terms of tonnage and value. These are derived from the 2008 updates to the FAF commodity O-D database for domestic movements. The "Other intermodal" category includes movements involving the water mode.

Table 13. Top five commodities moved intermodally (2008) (*52*).

Mode	Rank	In Terms of Tonnage	In Terms of Value
Air & Truck	1	Machinery	Electronics
	2	Electronics	Machinery
	3	Chemical products	Precision instruments
	4	Textiles/leather	Misc. mfg. prods.
	5	Other agric. products	Transport equipment
Truck & Rail	1	Cereal grains	Motorized vehicles
	2	Coal	Chemical products
	3	Other agric. products	Other foodstuffs
	4	Waste/scrap	Waste/scrap
	5	Other foodstuffs	Mixed freight
Other Intermodal	1	Coal	Electronics
	2	Metallic ores	Misc. mfg. prods.
	3	Cereal grains	Precision instruments
	4	Fuel oils	Pharmaceuticals
	5	Gravel	Machinery

3.7 Deepwater Ports

The structure of the U.S. maritime industry, including its domestic waterways component, is complex. The industry involves multiple public and private interests that operate under business models and public institutional models to support global and domestic commerce that keep the U.S. economy and the nation secure. Ports are the intermodal nodes of these operations and experience congestion to varying degrees depending upon factors related to physical, operational, and regulatory constraints.

Physical Infrastructure: Terminal acreage on which operators can work ships and store and move inbound and outbound cargo is a baseline indicator of the "on-the-ground" volumes any one terminal can handle. The length of wharf and the depth of a berth limit the size of a vessel that can be accommodated at that port. The number of cranes and type of yard equipment affect efficiencies—the more cranes that can work a vessel at once and well-utilized equipment systems in a yard, the better operational speed. The most recent information on U.S. ports' infrastructure is found on their websites.

Whether rail is on-dock or near the vessel or the cargo requires handling first by a short-line railroad to a place outside the terminal where large trains are built by larger railroads is a physical differentiator, as the latter increases time and cost. The number of gates through which trucks pass to drop off and pick up cargo can restrict operations if there is insufficient capacity for peak hour traffic and trucks back up onto local roads. More recently, national port security requirements call for container x-rays and there appear to be more visual inspections taking place at ports for inbound cargo.

U.S. ports that handle bulk, break bulk, and containerized cargo develop plans and capital improvement programs working with the terminal operators and other stakeholders including the public and government agencies to deliver physical infrastructure improvements at the port. One group of ports must work within a well-defined and limited footprint (usually in an urban area) and the other group has available land near the port for expansion. A third type of port facility is a "greenfield" port developed on land away from urban areas with little to no existing port infrastructure.

Industry Segments: Major segments within the industry are delineated within the context of type of cargo and type of vessel. The internationally accepted descriptions of cargo types are listed below (*70*):

- **Bulk:** Homogeneous cargo that is stowed loose in the hold of a ship and is not enclosed in a shipping container or box, bale, bag, cask, or the like
- **Break Bulk:** Conventional, non-containerized cargo that is shipped in units of one (such as non-containerized machin-

ery or trucks) or whipped in units or packages (such as palletized or boxed cargo)

- **Containerized:** Cargo placed within a container, i.e., a single rigid, sealed, reusable metal box in which merchandise is shipped by vessel, truck, or rail
- **General:** Products or commodities that are not conducive to packaging or consolidation e.g., timber, rolled newsprint, agricultural equipment
- **Refrigerated:** Perishable cargo such as food or pharmaceuticals shipped in a refrigerated, temperature controlled container, commonly referred to as a "reefer"
- **Roll-on, roll-off (RO/RO):** Cargo that rolls on wheels onto vessels specifically designed to accommodate such movements.

This list is not all encompassing but is sufficient for the purposes of understanding the general industry segments.

Generating Economic Benefits and Economic Security: As MARAD has reported, the trade activity of the Port of Los Angeles and the Port of Long Beach alone created 3.3 million jobs across the nation in 2005, a 200 percent increase from 1994. Nationwide, state and local taxes generated from trade activity grew from an estimated $6 billion in 1994 to more than $28 billion in 2005 (*46*). According to the American Association of Port Authorities (AAPA), in 2007, "port activity contributed more than $3.15 trillion to the Gross Domestic Product (GDP), while 13.3 million Americans worked in port-related jobs that generated nearly $650 billion in annual personal income and $212.4 billion in Federal, state, and local taxes (*71*).

International trade drives the ports and waterways industry and as the nation's GDP grows, so do international trade volumes. MARAD states that the combined value of foreign trade (imports and exports) represented 13 percent of GDP in 1990 and by 2006 it had risen to 22 percent. Should this trend continue, the value of U.S. foreign trade could reach 35 percent of the nation's GDP in 2020 and perhaps 60 percent in 2030. Since currently 95 percent of foreign trade by weight is moved by ship, the nation's ports and waterways will continue to play a critical role in our national economy and our national economic security. The American waterways network is used to move more than 2.3 billion tons of domestic and foreign cargo each year, primarily using private terminals for bulk products and commodities (*71*).

Deepwater Port Operating Structure: There are currently 121 deepwater U.S. ports, including those in Hawaii, Alaska, and Puerto Rico, on Lloyd's Maritime list. This list excludes inland ports and Great Lakes ports. The deepwater ports handle all types of cargo in containers, in bulk vessels, on break bulk or general cargo ships, and in RO/RO vessels. Liquid and dry bulk cargo is shipped in large vessels and therefore a large amount of tonnage is reflected at those ports at which they call.

The ports and waterways maritime industry is driven by private-sector companies and public port authorities that enter into contractual business arrangements with each other to move in-bound and out-bound cargo through a port. In the United States, deepwater public port authorities fall into two categories: the landlord port or the operating port. The AAPA defines these as follows:

- **Landlord port.** At a landlord port, the port authority builds the wharves, which it then rents or leases to a terminal operator (usually a stevedoring company). The operator invests in cargo-handling equipment (forklifts, cranes, etc), hires longshore laborers to operate such lift machinery, and negotiates contracts with ocean carriers (steamship services) to handle the unloading and loading of ship cargoes.
- **Operating port.** At an operating port, such as Charleston, South Carolina, the port authority builds the wharves, owns the cranes and cargo-handling equipment, and hires the labor to move cargo in terminal storage sheds and yards. A stevedore hires longshore labor to lift cargo between the ship and the dock, where the port's laborers pick it up and bring it to the storage site (*71*).

Recently, private-sector companies have invested in terminal development and have worked with the port authorities to privatize port development opportunities. It is widely recognized that for every public port authority in the United States, there is some slightly different factor in how they are structured, the level to which they are directly a government-run agency, or how they generate revenue and what they can do with that revenue.

Shipping Trends: The number of vessel calls is an indicator of the capacity of an individual port to accommodate a level of business over a year. By comparing year over year statistics along with the type of vessel making the call, variations can indicate growth or decline in the deepwater business in the United States.

In 2007, 6,867 oceangoing vessels made 63,804 calls at U.S. ports. Vessel calls were up 13 percent from 5 years earlier. Of the 2007 calls, 34 percent were by tankers, 31 percent were by container ships, 17 percent were by dry bulk vessels, and 10 percent were by RO/RO vessels. Also in 2007, 88 percent of the tanker calls were by double-hull tankers, up from 58 percent since 2002. Liquid natural gas (LNG) carriers accounted for less than 1 percent of the calls, but were the fastest growing segment over the last 5 years (*72*).

Foreign Waterborne Commerce Tonnage and Value: The total value of U.S. foreign waterborne commerce, counting both imports and exports, was $1.393 billion in 2007, an increase of 9 percent over the 2006 amount of $1.275 billion. This was

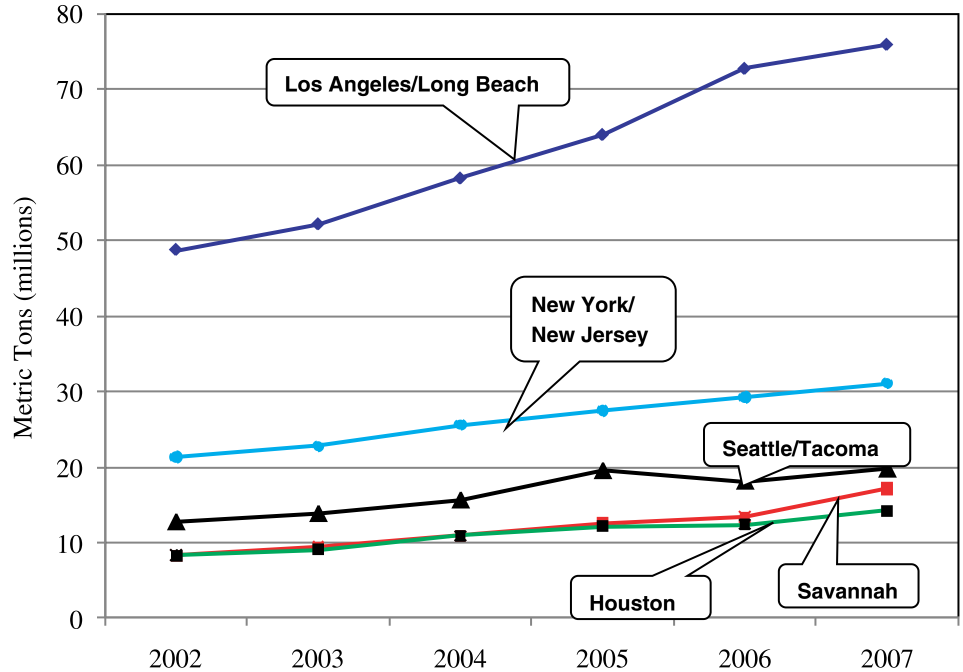


Figure 10. Tonnage of freight through top five U.S. ports (50).

the case even though 2007 total tonnage of 1.375 million metric tons declined 0.5 percent from the 2006 figure of 1.382 metric tons (*71*).

According to the 2008 updates to the FAF² O-D database (*52*), the volume of international imports (measured in tons of freight) through seaports has grown by about 14 percent between 2002 and 2008 while exports decreased by about 1 percent during the same period. This increase in volume of imports is expected to continue and has operational and environmental implications for drayage practices. Truck drayage is an integral part of the intermodal freight transportation network and the demand for short-haul trucking continues to rise with the growing trend of cargo freight.

Containerized Cargo: Containerized cargo is generally made up of goods of higher value than bulk cargo. The ports through which containers travel are critically important to getting this high value cargo to its destination on time, safely, and without damage or loss. From 2002 through 2007, U.S. foreign container trade increased by 51 percent and in 2007, the top ten ports alone accounted for 89 percent of U.S. container trade. Figure 10 shows the variation of the tonnage in million metric tons of container freight for the top five seaports in the United States.

Types of Freight: The U.S. Army Corps of Engineers (USACE) receives data from the Department of Homeland Security (DHS) that is collected from manifest information provided to U.S. Customs and Border Protection as cargo is imported to or exported from the United States. By weight, 95 percent of all goods entering the United States come via waterborne commerce. Table 14 lists the top five commodities shipped in 2008 as either imports or exports regardless of the type of vessel. These figures represent all waterborne foreign trade and include containerized, bulk, break bulk, and all other types of cargo.

For the containerized trade in 2007, Table 15 lists the top five import commodities and the top five export commodities by tonnage, 20-foot equivalent units (TEUs) and value in U.S. dollars. With containerized cargo, large volume and weight do not necessarily mean high value. The highest import value on the import table, for example, is in furniture, mattresses, supports, lamps, and lighting fitting, while the total tonnage is less than the number one commodity in tonnage, non-metallic mineral products. However, the volume in TEUs for furniture, mattresses, supports, lamps, and lighting fitting is the highest on the list. This is one reason why

Table 14. Top five commodities moved by water (2008) (*52*).

Rank	In Terms of Tonnage	In Terms of Value
1	Cereal grains	Crude Petroleum
2	Crude petroleum	Basic chemicals
3	Gravel	Cereal grains
4	Fuel oils	Other agric. products
5	Gasoline	Gasoline

Table 15. U.S. container trade—top five commodities ranked by tonnage (*73*).

Rank	Imports				Exports			
	Commodity	Million Tons	Thousand TEUs	Billion $	Commodity	Million Tons	Thousand TEUs	Billion $
1	Non-metallic mineral products	10.1	933.7	6.36	Waste and scrap	14.1	1,472.9	8.40
2	Furniture, mattresses, supports, lamps, lighting fitting	8.6	1,872.1	23.03	Plastics and rubber	9.7	1,342.2	18.95
3	Metallic ores and concentrates	7.6	551.3	11.68	Paper and Paperboard and Products	4.6	568.4	4.01
4	Base metal in primary or semi-finished forms	6.8	791.1	20.40	Gravel and crushed stone	4.6	342.8	0.86
5	Alcoholic beverages	6.6	486.5	12.28	Animal Feed and products of animal origin	4.4	435.4	1.72

container ports in the United States report their volume statistics principally in TEUs, as it has become a common way of comparing themselves with competitive container ports worldwide.

Performance Measures: In 2003, MARAD conducted a survey to gauge international carriers' perceptions of "mainstream container services." Twenty-one of the 22 carriers serving the trade responded. The respondents were asked to evaluate U.S. ports in comparison to Canadian ports according to 14 features common to most container ports. Several of the indicators mentioned in project interviews were related to physical and operational constraints. These included the following:

- Security
- Use of technology
- Vessel turnaround time
- Rail access away from the terminal
- Hours of operation
- Road access at the terminal
- Road access away from the terminal
- Cost per move
- Truck gate time, queuing lanes (*74*).

There is constant competition among carriers, terminal operators, and ports to increase volume over previous years and to maximize profits. The Georgia Ports Authority (*75*) noted that U.S. ports are well aware of this and have increasingly hired persons with work experience in the railroad, trucking, global marketing, and warehousing and logistics industries.

Given the emergence of significant competition from newly developed or planned ports in Canada and Mexico, U.S. ports are increasingly emphasizing their roles in facilitating velocity flows through to the supply chain's ultimate destination. Whether containers enter the United States through West Coast or East Coast ports or from Canada or the U.S. Gulf Coast, it is usually a race to provide rail and roadway connections for on-time delivery to the heartland business centers in Chicago and other major cities.

Stakeholders: Ports in urban areas in particular are feeling the pressure from competing land uses for ferry systems, cruise terminals, "gentrification" housing, retail developments, and cultural attractions. The unique challenges faced by these ports mean that an array of stakeholders beyond those in the shipping business have a "stake" in future port operations.

Table 16 lists stakeholders that have an interest in how ports operate, how they are regulated, what impacts they have on the community, and what businesses and labor they require to support their operations. These stakeholder interests relate to terminal activities waterside, "inside the fence" meaning "on-terminal," "outside the fence" meaning in the immediate surrounding and further inland areas, and internationally as the United States complies with international standards and requirements that are so critical to global trade.

New Technologies: U.S. companies and international businesses are constantly developing new technologies and ways to enhance the movement of cargo not only from port to port but also throughout the point-to-point intermodal supply chain. This has meant an increase in jobs for Americans in shipyards, on port terminals, in related warehousing industries, and in logistics management to cite just a few interrelated job-generating centers that are needed to keep freight flowing throughout the country.

Table 16. Stakeholder groups and their locational focus of interest for U.S. deepwater ports.

U.S. Deepwater Ports Stakeholder Groups	Waterside	Inside the Fence	Outside the Fence	International
Federal Agencies and Elected Officials	X	X	X	X
State Agencies and Elected Officials	X	X	X	
Local Agencies and Elected Officials	X		X	
Public Citizens and Neighborhood Organizations	X	X	X	X
Port Authorities	X	X	X	X
Terminal Operators	X	X	X	X
Carriers	X	X		X
Shippers	X		X	X
Labor—Unionized	X	X	X	X
Labor—Non-Union		X	X	
Railroads		X	X	
Trucking Companies		X	X	
Customs Brokers		X	X	X
Logistic Providers	X	X	X	X
Insurance Providers	X	X	X	X
Warehousing			X	
Fuel Suppliers	X	X		
Maintenance Companies		X		
Engineers	X	X		
Security Firms	X	X		
Technology Firms	X	X	X	X
Maritime Exchange Organizations	X	X		
Pilots	X			
Tribal Organizations	X		X	

Established structural and operational relationships among supply chain service providers are rapidly changing in a highly technology-driven society. Forces of change in the intermodal transportation environment are driving new and emerging technologies and regulations related to vessel size and operations, the environment, security, and safety. As these dynamic forces bring challenges to bear upon the ports and waterways operators to provide sufficient capacity and regulatory compliance, they must ever strive to provide their customers with greater system efficiencies and less cost.

Human Resources: From 2002 through 2007, 16,300 jobs have been added in the water transportation and port service industries (Table 17). In 2007, transportation accounted for about 39 percent of the combined employment, up from 36 percent in 2002 (*50*).

Table 17 breaks out the employment figures between those that work in the port services area and those that work in the inland waterways. These 2007 figures show a total of 99,800 jobs for port services, of which a little less than half or 45,200 are in cargo handling jobs. For the water transporta-

Table 17. Employment in water transportation and port services, 2002–2007 (Thousand Jobs) (*50, 76*).

Segment	2002	2003	2004	2005	2006	2007	% Change 2002-2007
Transportation	52.6	54.5	56.4	60.6	62.7	64.3	22.2
Ocean, Coastal & Lakes	32.3	33.7	35.2	37.3	39.1	40.0	23.8
Inland	20.3	20.8	21.2	23.3	23.6	24.3	19.7
Port Services	95.2	93.8	91.5	93.9	99.3	99.8	4.8
Cargo Handling	39.6	40.8	40.8	42.8	45.6	45.2	14.1
Other	55.6	53.0	50.7	51.1	53.7	54.6	-1.8
TOTAL	147.8	148.3	147.9	154.5	162.0	164.1	11.0

tion segment, a total of 64,300 jobs were found providing services along the inland waterways, ocean, coastal waterways, and lakes in positions that were not classified as port services. Of this total for 2007, 24,300 are employed in the inland waterway industry segment.

3.8 Inland Waterways

Inland river ports and terminals are designed to load and unload barges that are pushed or pulled by towboat along the nation's navigable waterways. The Inland Rivers, Ports, and Terminals (IRPT) Association defines an inland river port as an intermodal transportation center. It finds that the river port is "first of all, an intermodal transportation and distribution center. Its secondary activity is industrial production and processing" (*77*). Grains, petroleum, LNG, ore, and gravel are but a few of the major commodities moved by tug and barge along the waterways not only from port to port but also internationally. The Great Lakes ports handle similar bulk cargoes on vessels specifically designed for Great Lake transport.

In the United States, the inland waterway freight transportation system generally consists of three types of systems: Coastal and Intracoastal Waterways, the Great Lakes System, and Inland River Systems. These systems are further discussed below.

3.8.1 Coastal and Intracoastal Waterways

In the United States, "coastal waterway" is a term commonly used by the freight community to describe the coastal shipping routes along the Gulf and Atlantic Coasts and intracoastal waterways just inland of the coastline. By contrast with deepwater ports, coastal waterways ports are of a smaller scale and do not typically haul containerized cargo, nor do they handle vessels with deep drafts.

The Intracoastal Waterway runs along the Eastern Atlantic seaboard and along the Gulf Coast. It is comprised of two segments: the Gulf Intracoastal Waterway (GIWW) and Atlantic Intracoastal Waterway (AIWW). Most of the traffic moving through the GIWW includes shallow-draft dry bulk and tank barges, while most of the traffic along the AIWW consists of recreational boaters and a limited extent of commercial vessels (*33*). Along the northern portion of the Atlantic coast, petroleum products and industrial heavy fuels are moved between the Northeast and Mid-Atlantic states primarily along the Chesapeake Bay, Delaware Canal, and Cape Cod Canal.

The coastal and intracoastal waterways and ports are used by shallow-draft vessels originating from or destined to inland rivers and are used for transferring loads or picking up goods. The network of the coastal and inland waterway system is approximately 25,000 miles, with about 13,000 miles belonging to the network of coastal and intracoastal waterways and 12,000 dedicated to inland waterways traffic (*78*).

3.8.2 Great Lakes System

The Great Lakes System is made up of seven waterways linked at a dozen lock sites. Oceangoing vessels gain access to the Great Lakes through the St. Lawrence Seaway. In terms of tonnage, the largest ports within the Great Lakes System include Duluth-Superior, Chicago, Detroit, and Cleveland. The terminals at these ports generally handle dry bulk cargoes, including iron ore, grain, coal, sand, stone, and lumber. Special vessels, known as "lakers," can range as long as 1,000 feet and carry up to 70,000 tons of gross cargo. Some oceangoing vessels operated on the Great Lakes, however, often do not exceed 35,000-dead weight tonnage (dwt) capacity (*33*). Due to weather extremes and climate associated with the Great Lakes, navigation is seasonal and typically lasts no longer than 8 months. Given the common boundaries of Canada and the United States around the Great Lakes, there is an international aspect to the shipment of cargo through the St. Lawrence Seaway and around the Great Lakes.

3.8.3 Inland Rivers and Waterways

The network of inland rivers and waterways moves a significant portion of tonnage across the continental United States, mostly in dry bulk, commodities, and fuels. The three largest inland river systems include the Mississippi River system, Columbia-Snake Rivers in Washington and Oregon, and the Black Warrior-Tombigbee Rivers in the Alabama-Gulf region (*33*). The Mississippi River system, including the Ohio and Missouri tributary systems, is the largest inland freight waterway in the United States. The system extends to approximately 6,000 miles and connects freight to 17 states. It is maintained by the USACE.

All inland river systems are shallow-draft systems and channel depths are not typically greater than 12 feet. Such depth is what prevents oceangoing vessels from utilizing inland waterways. Also characteristic of inland water systems are the types of vessels that utilize them, specifically barge and tug, and towboats. These vessels are typically narrower and navigable with pusher-style towboats, which navigate them to the locks. Each barge can carry between 1,000 and 1,800 tons of cargo. Grain elevators and coal depots are major terminals for these vessels (*33*).

The IRPT Association uses the following river basin designations to organize its board of directors. It assists those unfamiliar with the waterways systems, as seen in Figure 11, to visualize and understand the interconnected waterways systems.

Figure 11. U.S. marine highways (46).

- Upper Mississippi (North of Ohio River)
- Lower Mississippi (South of Ohio River)
- Ohio River
- Illinois River
- Missouri River
- Arkansas-White-Red-Ouachita Rivers
- Southeast Rivers (Tennessee, Tennessee-Tombigbee, Black Warrior-Tombigbee, Coosa, Alabama, Tri-Rivers)
- Gulf Intracoastal
- Pacific Coast (Columbia, Snake, Sacramento, Vancouver)
- Unclassified.

3.8.4 Locks and Dams

Locks are man-made structures that allow vessels to move between higher waters backed up by a dam structure and lower waters below the dam structure. The dams work to maintain navigable water levels, and the locks open and close mechanically to allow vessels to move up and down the river systems. These locks and dams are built and maintained by the USACE under appropriations from the U.S. Congress and using the Inland Waterways Trust Fund “user fee” or “user tax” on the waterways industry based on fuel consumed in inland waterway transportation. As the U.S. MARAD notes, “much of our lock and dam infrastructure was built 50–80 years ago in an era when vessels were much smaller” than they are today (*72*). USACE is working with the Inland Waterways Users Board, comprised of industry members, including shippers and carriers, to make recommendations to Congress concerning the prioritization of inland navigation projects. The aging infrastructure and inadequacy of funding is of major concern to the maritime industry.

In terms of trust fund value, the Inland Waterway Trust Fund earned $101.5 million in fiscal year 2007. This included $91.1 million paid by the barge and towing industry and $10.4 million in interest. The Fund also disbursed $159.8 million for construction projects leaving a balance of $209.4 billion, its lowest level since 1993 (*73*).

The USACE owned or operated 257 lock chambers at 212 sites at the close of fiscal year 2005; however, only 195 sites with 240 chambers received funding for repairs or upgrades. Nineteen Fox River locks (17 locks and 2 guard locks) were transferred to the State of Wisconsin in 2004. Many of the 212 lock sites serving navigation include multi-purpose dams, and of them, 46 lock-associated dams currently produce hydroelectric power. Many of the locks west of the Mississippi River have higher lifts than those in the east due to the younger age of the infrastructure in the western United States. For example, in Oregon, the John Day Lock has the highest lift (110 feet) of any U.S. lock in comparison to the collective 404-foot lift of all 29 locks on the upper Mississippi River (*73*). Table 18 shows the locations and characteristics of the inland waterway facilities.

Physical Infrastructure: As previously indicated, an inland port is considered to be an intermodal transportation and

Table 18. Geographic distribution of U.S. inland waterway facilities (*73*).

Type of Facility	Great Lakes	Inland (Shallow)	Atlantic (Shallow)	Gulf (Shallow)	Pacific (Shallow)
Commercial Facilities	600	2321	587	1093	363
Cargo	378	1576	198	475	151
Service	170	484	274	505	171
Unused	52	261	115	113	41
Lock Sites[1]	4	1	14	44	9
Lock Chambers[1]	6	1	14	44	13

[1] Locks, including five control structures, owned and/or operated by the USACE at the close of FY 2005.

distribution center. Its secondary activity is industrial production and processing. The river locations are designated by miles along the river so that ports and terminal locations will be listed as being located at a particular mile post along a particular river (*77*). However, the physical facility is more than just a place to load and unload barges and tankers. The inland port system includes railway, roadway, airway, pipeline, and waterway. Distribution facilities include storage structures such as transit sheds, warehouses, open storage, tanks, and bulk storage. Table 18 shows the distribution of physical infrastructure of inland waterways in the United States.

The 12,000 miles of inland waterways operate as a system much like highways, and commerce moves on multiple segments. They not only serve commercial navigation but also provide hydropower, flood protection, municipal water supply, agricultural irrigation, recreation, and regional development in many cases. The Port of Louisiana stretches 54 miles along the Mississippi River. It is the largest tonnage port in the western hemisphere and comprises facilities in St. Charles, St. John the Baptist, and St. James Parishes. In contrast, Duluth-Superior is the largest inland port on the Great Lakes and is one of the premier bulk-cargo ports in North America. However, its navigation season usually begins in late March and continues until mid-January.

Inland Waterway Operating Structures: There are 360 inland commercial ports and terminals in the United States including the Great Lakes and coastal waterways (*71*). These inland waterway systems play an important role in the distribution of freight between deepwater ports and the highway and rail systems. Much of the cargo carried on inland waterways consists of dry bulk, commodities, and fuels. Generally, distribution of such cargo occurs at either an inland river port or inland river terminal, which are described below.

- **Inland River Port.** The IRPT Association defines an inland port as a complex of adjacent or nearly adjacent terminals operating under some degree of influence or control by a state (or interstate) chartered port commission or authority. In most cases, the port commission/authority sells or leases the land used by a terminal company much the same as an industrial developer does in an industrial park. Generally, the word "port" is meant to include the terminals in the area which the authority developed and "terminal" refers to isolated facilities that are not in an organized port area (*79*).
- **Inland River Terminal.** Terminals are located on the waterfront for the purpose of loading and unloading barges. Each such individual terminal is an intermodal transportation hub. Terminals come in three types: (i) a general purpose terminal is designed to handle a wide variety of commodities often in bundles, coils, large bags, drums, pallets, and such. Most ports will have only one terminal but some large ports may have several. Because there may be many customers, they are also often called public terminals; (ii) special purpose terminals are specially designed to handle only one type of commodity and they accordingly have a capacity to move large tonnages rapidly. Examples are grain, fertilizer, coal, petroleum products, cement, sand and gravel, stone, and similar terminals, all of which can easily be identified by their permanent liquid or pneumatic pipeline or conveyor system; and (iii) industrial terminals, unlike the others, are not a part of the intermodal system but are designed to service a specific industrial plant or processing facility. Industrial plants at an inland port or at isolated terminal locations have an unusually significant beneficial effect on the local and regional job market. This, in turn, has a strong effect on the economy (*77*).

Industry Segments: Tugboats, towboats, barges, and tankers make up the inland waterway fleet of vessels that work together to move bulk agriculture products and chemical and petroleum products on the nation's waterway systems. The type of waterway also defines the industry segment, e.g., Great Lakes, Coastal and Intracoastal, and Inland Waterways. The Center for Ports and Waterways in 2007 identified the entire inland waterway system as including the ports, terminals, rail, and truck components of moving cargo from point to point within the system. They note that certain types of analysis can be done on a system-wide level, but that when it is desirable or necessary to focus on only certain segments, it is best to focus on the Mississippi River Basin, Ohio River Basin, the Gulf Intracoastal Waterway, and the Columbia-Snake River System (*80*). In 2005, 91 percent of internal tonnage was carried along these waterways. This report does note USACE statistics for these waterways.

Commerce Tonnage and Value: Activities and cargo handling along the inland waterways and at the ports and terminals within the system are measured over time by the amount of tonnage carried per mile of waterway and the number of trips per ton-miles. It is not the value of the cargo that is a distinguishing factor so much as the amount of tonnage handled over time. Table 19 lists the total tonnage, ton-miles, and trip ton-miles by waterway for 2006. Figure 12 shows the share of

Table 19. Performance of inland waterways—2006 (*73*).

Waterway	Length (miles)	Million Short Tons	Billion Ton-Miles	Billion Trip Ton-Miles
Atlantic Coast	1142	2.8	0.2	0.3
Gulf Coast	1992	180.9	25.3	92.1
Mississippi River System	8292	1508.5	412.56	1110.8
Pacific Coast	1192	68.9	5.6	12.5

the domestic freight tonnage movements among the major segments of the inland waterway system based on 2006 data.

As noted previously, value is less important on the inland waterways because so much of what moves is relatively low-value bulk tonnage. Some of those bulks (e.g., refined petroleum products, grain) can have quite high value but there are also movements of aggregates and sand and materials with very low unit values. Except on the Columbia-Snake River system, there are no significant volumes of containerized goods moving on the inland water system (and even there it is small) so the focus on tonnage is entirely appropriate. From a national systems perspective, inland water transport is significant because of the savings it offers compared to massive truck or even train movements.

Types of Commodities: Table 20 lists the major waterborne commodities moved by the inland waterways in millions of short tons and the percentage change.

Stakeholders: Users primarily include the navigation industry, shippers, U.S. Coast Guard (USCG), recreation boaters, and the military. Among the inland waterway freight community, approximately 20 percent of coal and 60 percent of grain exports are shipped through the inland waterway network (*78*). User groups such as the American Waterway Operators (AWO) track data and statistics associated with the use of the nation's inland waterways. Table 21 shows the various inland waterways stakeholder groups. The Inland Waterway Users Board is an independent, Federal Advisory Committee. The purpose of this user/stakeholder group is to formalize recommendations to the U.S. Congress and Secretary of the Army on the spending and priorities from the Inland Waterways Trust Fund for construction and rehabilitation projects on fuel-taxed waterways (*82*).

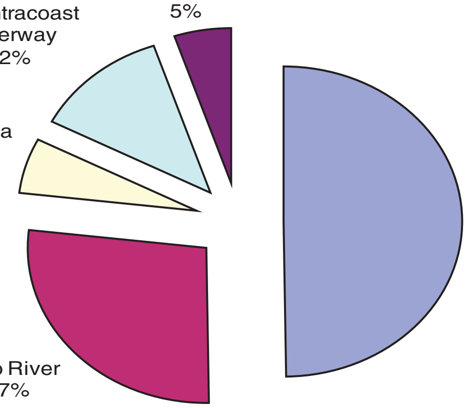


Figure 12. Composition of internal tonnage by waterway (million short tons) (81).

Table 20. U.S. domestic waterborne traffic by major commodities in 2006 (*73*).

Commodity	Coastwise		Lakewise		Internal	
	Million Tons	%	Million Tons	%	Million Tons	%
Coal	9.8	-0.9	20.8	-1.5	177.5	-2.4
Coal Coke	**	-100.0	0.4	-44.8	5.7	11.7
Crude Petroleum	36.8	-18.0	**	0.0	32.7	-1.1
Petroleum Products	109.1	-2.6	1.5	4.4	126.9	5.2
Chemical and Related Products	9.6	-7.0	0.1	-13.9	48.9	-2.6
Forest Products (i.e., wood chips, saw)	1.9	-16.6	**	-73.8	5.0	-20.7
Pulp and Paper Waste	**	-97.7	**	0.0	**	-76.8
Sand, Gravel and Stone	8.7	3.3	25.0	-6.1	87.4	2.4
Iron Ore and Scrap	0.5	-32.0	42.9	6.4	11.2	3.4
Non-Ferrous Ores & Scrap	**	**	**	0.0	5.8	-7.4
Sulphur, Clay and Salt	**	-96.4	0.9	-17.7	7.4	-2.4
Primary Manufactured Goods	10.6	17.2	4.3	10.2	30.9	0.6
Food and Farm Products	5.3	-13.3	03	4.9	73.6	3.9
All Manufactured Equipment	9.4	-2.2	0.1	**	9.5	-3.3
Waste and Scrap, NEC	**	**	**	0.0	1.4	-1.9

** denotes tonnage less than 50,000 tons or extreme percentage change.
NEC = Not Elsewhere Classified; % = percentage change between 2005 and 2006.

Table 21. Stakeholder groups and focus of interest for U.S. inland waterways.

U.S. Inland Waterways Stakeholder Groups	Riverside/Great Lakes/Coastal & Intracoastal Waterways	Landside at Terminal	Related Industrial and Economic Development Areas	Pipelines
Federal Agencies and Elected Officials[1]	X	X	X	X
State Agencies and Elected Officials	X	X	X	X
Local Agencies and Elected Officials		X	X	X
Public Citizens and Neighborhood Organizations	X	X	X	X
Port Authorities	X	X	X	X
Terminal Operator	X	X	X	X
Carriers	X	X		X
Shippers	X	x	X	X
Labor—Unionized	X	X	X	X
Labor—Non-Union		X	X	
Railroads		X	X	
Trucking Companies		X	X	
Customs Brokers		X	X	
Logistic Providers	X	X	X	
Insurance Providers	X	X	X	X
Warehousing			X	
Grain and Raw Material Elevator Operators		X	X	
Fuel Suppliers	X	X		X
Petrochemical and Petroleum Industry	X	X	X	X
Maintenance Companies		X		
Engineers	X	X		X
Security Firms	X	X		X
Technology Firms	X	X	X	X
Pilots	X			
Tribal Organizations	X		X	

[1] - Federal agencies include the U.S. Department of Agriculture, which monitors commodity prices and production levels

Industry Employment: In 2006, the Bureau of Labor Statistics (BLS) reported 22,540 occupations associated within the Inland Waterway Transportation industry. The industry grew by 1,450 more occupations in 2007. Transportation and material moving occupations make up about 75.8 percent of the inland waterway industry employment, while the remaining 24.2 percent consist of occupations associated with management, business operations, sales operations, installation and maintenance, administration, and service-related occupations (*76*).

CHAPTER 4

Freight Mobility Constraints

This chapter also presents analysis of information gathered from interviews and survey. Based on the analysis, this chapter defines freight mobility constraints, potential causes, and performance indicators for monitoring and measuring the constraints. This chapter also discusses the different types of constraints from multimodal perspectives.

4.1 Defining and Characterizing Freight Mobility Constraints

Results from the interviews and survey conducted as part of this project indicated that there is no formal definition of a freight mobility constraint. Such a definition or taxonomy is lacking among all modes both from public-sector and private industry perspectives. Freight mobility constraint is defined in different ways, but all definitions have a common theme. The following are some of the definitions:

- Any infrastructure, institutional, financing, operational, or environmental deficiency that impedes—or has a significant likelihood of impeding—the safe and efficient movement of goods in a sustainable manner.
- Freight mobility constraints are operational, infrastructure, or institutional issues that prevent the free/unencumbered flow of freight.
- Any event, situation (e.g., construction, customs/border delays, weather-related road closures), or physical feature such as a physical design deficiency that impacts the movement of freight.
- Impediments or obstacles, including infrastructure, regulations, or congestion, that prevent freight from moving freely, quickly, and efficiently anywhere in the transportation system between the origin and destination of the shipment.
- Any system limitation, policy decision, operational concern, or communication issue that undermines the potential fluidity of any segment of the logistics stream.
- Lack of connectivity between freight modes, congestion-laden networks, lack of technology or equipment—all of which would hinder efficient freight traffic flow.
- Any internal or external factors that define the limits on the amount of freight that can be moved between two points efficiently, safely, and in an environmentally acceptable way. These factors include the characteristics of the physical infrastructure, operational procedures, and regulatory regimes.
- Any factor or factors connected with highway operations that significantly add to the cost of moving freight, e.g., delay, truck operating costs due to congestion and terrain, undersized intermodal facilities.

Based on this range of possible definitions, a freight mobility constraint may be generally defined as *a physical or infrastructure deficiency, regulatory action, or operational action that impedes or restricts the free flow of freight either at the network level or at a specific location. Mobility constraints create additional costs or affect service levels negatively*.

A freight mobility constraint can be caused by physical, operational, or regulatory or policy factors. These categories of constraint types or causes are defined below.

- *Physical Constraints*—any geometric or infrastructure conditions that constrain freight operators from operating at designed, safe speeds, and within legally required parameters
- *Operational Constraints*—practices, events, or occurrences that constrain system throughput, and constrain optimal and legal operating conditions
- *Regulatory Constraints*—Federal, state, or local regulatory requirements that restrict the flow of freight through the system.

The following sections discuss the causes of freight mobility constraints encountered on highways, railways, and at deepwater ports and inland waterways. Examples of the three categories of constraints are also presented.

4.2 Causes and Locations of Mobility Constraints

4.2.1 Highways

Many causes of freight mobility constraints on the highway system were noted by the respondents to the surveys and interviews. While many of the constraints affect only specific locations, corridors, regions, or types of facilities, others are more systemic to the interstate highway system and can impact international freight movements. In addition, the causes of mobility constraints are frequently interrelated.

4.2.1.1 Physical Constraints

Physical infrastructure deficiencies are the most prevalent constraints cited by respondents. These deficiencies may be system-wide or site specific. Examples of physical constraints on the highway system include:

- Ramp meter locations that cause trucks to stop at a ramp terminal before attempting to merge into high-speed traffic
- Long, steep grades lacking passing lanes, particularly on mountainous roads
- Inadequate radii of loop ramps, at intersections or driveways into freight generators
- Obsolete freeway ramps that were built in an era of shorter trucks/trailer combinations with shorter turning radii
- Inadequate vertical or horizontal clearances (low bridge clearance—insufficient height for containers)
- At-grade highway rail crossings in the vicinity of freight generators
- Lack of adequate ingress/egress gates at ports, intermodal terminals, or rail classification yards
- Increase in intermodal freight traffic near major ports such as in Southern California without a commensurate increase in capacity to local infrastructure
- Lack of sufficient rest area space for trucks
- Lack of alternate routes for large trucks
- Lack of available and secure truck parking.

4.2.1.2 Operational Constraints

Freight mobility constraints are not limited to physical infrastructure deficiencies. Operational characteristics of both the transportation system and motor carriers' customer bases also create freight mobility constraints. Motor carrier customers frequently require pickup and delivery appointments during peak travel periods, causing carriers to add more trucks and drivers to maintain service levels and exacerbating congestion in already congested areas. Operational characteristics of the transportation system that impose constraints may include the following:

- Lack of advance signing on crossroad approaches to interchanges
- Road construction activities
- Lack of traffic signals timed for large truck movements in areas of heavy truck volume
- Slow driver check-in/check-out at ports
- Lack of 24/7 access to intermodal facilities
- Poorly marked alternate routes
- Inadequate traveler information on incidents and roadway status.

4.2.1.3 Regulatory/Policy Constraints

Regulatory actions or public policies also play a major role in restricting truck freight movement. Public policies or regulations that negatively impact efficient freight movement vary in scope and range from local to international. Local route restrictions, zoning laws, and parking restrictions may limit truck access to various areas. At the state level, it may be a lack of alternate routes for trucks or alternate routes with insufficient signage. A lack of regulatory harmonization between different jurisdictions (e.g., cities, states, countries) can also constrain freight movement.

The most often cited national policy-based constraints are safety- and security-related restrictions and regulatory compliance. These policies may restrict freight mobility on several levels, create delay, and increase motor carrier costs. International shipments by land face delay at U.S. border crossings as a result of security regulations, while local security regulations limit truck access to many office buildings and government facilities. Other types of policy-based constraints impose burdens on the efficient movement of freight. These may include:

- A lack of interoperability or reciprocity in the use of toll passes/transponders that are issued by various states; trucks will need several passes to travel between states
- A lack of reciprocity between states in inspecting trucks, which results in repeated safety inspections of the same vehicle in different states
- Restrictions on the use of drivers by labor agreements
- Local land use and zoning laws
- State roadway funding mechanisms such as toll facilities
- A lack of harmonization between state size and weight regulations
- U.S. border crossings and other security-related restrictions
- Route restrictions on longer combination vehicles
- Access/parking restrictions near office and government buildings
- Hazmat route restrictions
- Central business district (CBD) truck restrictions
- Safety- and security-related policies that affect the availability of drivers.

4.2.1.4 Locations of Constraints

In developing low-cost, quickly implementable improvements to address freight mobility constraints on the highway system, it is important to understand not only the causes but also the locations within the freight transportation network where these constraints are most severe and prevalent. Urban and metropolitan areas were identified as being the source of the majority of mobility constraints. In particular, the northeastern United States has the most infrastructure deficiencies, perhaps due to the age of the infrastructure and urban areas that are located closer together. It was, however, noted that large urban and metropolitan areas offer alternate routes more frequently than small to mid-sized areas.

In addition to regions of the country, respondents noted that mobility constraints significantly impact several different types of facilities. Facilities with the most inefficient freight movements include marine ports, U.S. land border crossings, major bridges in the Northeast, and unionized facilities, according to the data collected.

Congestion on the highway system is most apparent at bottlenecks such as interchanges, as opposed to mainline highway links. The locations of most physical constraints include:

- Interchanges, particularly ones with at-grade merge and weave conditions such as occur at cloverleaf interchanges
- Areas of "lane drops" where trucks must change lanes to continue a through movement
- Short acceleration and deceleration lanes, which do not allow trucks to gain adequate speed to merge into traffic or to slow down outside of a general purpose lane
- Steep grades
- Metered freeway on-ramps
- Intersections with inadequate numbers of turn lanes or through lanes.

The locations of operational constraints include the following:

- Construction zones
- Signalized intersections
- Weigh stations
- Toll facilities
- Port terminals
- Border crossings
- Intermodal connectors
- Rail yards.

4.2.2 Railroads

The respondents were also asked to list and rank constraints that significantly impact rail freight mobility. The top ranked freight mobility constraints are:

- **Constrained Capital Budgets**—The number one barrier is constrained capital budgets. This is why the industry has put so much of its public and government relations effort into getting across the message that their financial returns must be adequate to support reinvestment in the industry. Railroads need to achieve returns greater than the cost of raising new capital, in order to avoid loss of capital through decreasing sales of common stock, wearing out of track and equipment, and eventual abandonment of facilities.
- **Skilled Labor**—The second ranked barrier is the task of supplying skilled labor. Demographic trends mean that a great many seasoned railroad employees are at retirement age. While replacement of labor with high-productivity capital equipment continues at a rapid pace, the hiring and training tasks facing railroads are of large scope and challenging content.
- **Federal and State Regulations**—The industry has pushed for more use of performance-based safety regulations with automated monitoring—in place of the age-old regime of command and control rules backed up with visual inspections. One respondent noted the implications of community objections to increased rail—the largest constraint on rail-based mobility is likely to be local regulation, and in particular the desire of towns to avoid hosting freight handling facilities. This is happening on a small scale with small transload facilities on short lines and on a grand scale with the resistance of northern Illinois suburbs to the increased use of the Elgin, Joliet, and Eastern Railway (EJ&E) as a freight route. This issue has major implications for the rail industry and its ability to solve freight mobility issues for the country.

Rail infrastructure consists of track and structures, terminals or yards, locomotives, cars, and signals and communication systems. Thus constraints to the movement of freight by rail can be defined in terms of these infrastructure components:

- Mainline throughput capacity restrictions seem to be the most serious freight mobility constraint facing railroads at this time, although the opinion was far from unanimous.
- Terminals and their switching efficiency seem to be the next most persistent constraint. While merchandise or manifest trains (sometimes referred to as "loose car" railroading) requiring handling in classification yards seem to be in decline relative to unit and double-stack trains (DSTs), bottlenecks persist in car switching, train marshalling, and running maintenance/train servicing functions handled in railroad terminals.

  Considerable tension exists between short-line operators and the large (Class I) railroads at the point of their interface—typically, a terminal or switching facility owned by the Class I. If the terminal is congested, the owner's supervisor may move his own trains in preference to the short lines. In this manner, the short-line operation may become congested as well, and its crews may "time out" on the hours of service law. Since the short line does not own the facility, it may feel it has no ability to improve the situation.

- Signaling and telecommunications upgrades are a major area in which increased investment is needed. There are several issues: First, it is often difficult to obtain skilled manpower for the design, installation, and maintenance of the industry's signaling equipment, much of which is outdated. Second, technology is advancing at a pace that sometimes causes managers to be concerned that new investments will be obsolete quickly. Third, developments such as Positive Train Control (PTC) are expensive, would need to be implemented over extensive territory, and should be interoperable among connecting but also competing railroads.

  Communications, signaling, and information (CS&I) projects always seem to be on the critical path for capacity additions—and similarly, worker skills in CS&I seem always to be among the most constrained.
- Locomotive and freight car investments are considered to constrain freight mobility by rail. While equipment is mobile, i.e., not fixed in location (which reduces one kind of resource misallocation risk), it is also peripatetic (i.e., it is hard to constrain to its highest and best uses, as good asset utilization principles require). It is always a challenge for railroads to balance the supply of equipment with the demand for it. Innovations such as shipper-provided rolling stock, efficient pooling of intermodal and auto-rack cars through TTX Company (which supplies railcars and related freight car management services to the North American rail industry) , and de-prescription of *per diem* rates have helped to make provision of rolling stock more efficient. Improved near- and mid-term forecasting of customer demand for equipment would help. These efforts could be further enhanced by implementation of reservation and auction systems yet to be developed.
- Proper information for operational management has been a problem in the rail industry over the years. New investments are being made more or less continuously, but opportunities for improvement still exist.

Some contend that most of the interruptions to velocity come at and around interchange points. Much of the friction is caused by interference with people movements (passenger trains, peak hour traffic, etc.). Competition between passenger and freight rail is increasing, causing substantial interruptions to flow in urban areas. The mismatched availability of labor and related resources between the transport modes at the interchange points exacerbates the problem.

Survey respondents representing short-line rail and regional railroads identified the following as the most severe and persistent freight mobility constraints:

1. Signaling restrictions or optimal signaling
2. Lack of locomotive power and freight cars
3. Switching inefficiency
4. Speed restrictions in urban areas
5. Vertical double-stack restrictions.

4.2.3 Deepwater Ports and Inland Waterways

Factors limiting the ability of external transport carriers (ship, rail, and truck) to access a terminal facility in a timely and efficient manner and to optimize the freight movement through the terminal constitute a constraint. This includes any factor that causes delay in either receipt or delivery of cargo. Another substantial constraint on mobility comes from the mismatched structure of labor resource availabilities in the various elements of the transport chain. Ship operators, longshoremen, motor carriers, railroad crews, warehouse operators, and other interested parties work on substantially different and mismatched schedules, and efficient transfer cannot take place unless there is synchronization.

Of relevance to inland waterways cargo movements are factors that cause traffic restrictions. For example, insufficient clearance or flooding that can cause traffic to slow or stop will result in delay. Freight mobility constraints result from the inadequacy of the capacity of freight (intermodal) connectors to meet demand as well as regulatory and operational factors.

The main freight mobility constraints facing port terminal operations can be generally categorized as regulatory and operational, e.g., driver shortage, information technology (IT)/information lag. The respondents all agreed that safety regulations do not impede efficient port terminal operations. Planning and environmental regulations (e.g., requirements related to clean air biodiesel fuel) in and of themselves do not impose unwarranted burdens on mobility and operations. The bigger burden is the erratic and unpredictable fashion in which the environmental laws and regulations are applied in the development of mobility projects.

As with environmental regulations, the security regulations in themselves are not considered to be significant burdens on mobility. Security regulations and requirements add to operating and transport costs, and cause modest inefficiencies in the use of space at transport nodes. However, their overall impacts on mobility and velocity are modest and manageable. The following causes of constraints were identified.

4.2.3.1 Operational Constraints

The following are examples of significant constraints that emanate from operational problems:

- Mismatched structure of labor resources resulting in inefficient transfers

- Lack of truck appointment pickup and dropoff systems
- Lack of expanded port gate hours
- Lack of willingness to culturally accept working in off-peak hours
- Difficulty adjusting operations to cargo flow peak demand periods
- Differences in shippers, port, and trucker operating hours
- Inadequate trained labor
- Equipment failures and maintenance requirements
- IT/information lag times.

4.2.3.2 Regulatory Constraints

Following operational constraints, regulatory constraints were found to be a problem considering that regulations can affect physical capacity and operational conditions. Two regulatory issues cited are related to security and air quality requirements. Terminal operators must have sufficient areas to accommodate Vehicle and Cargo Inspection System (VACIS) x-ray machines. The extra movement of a container onto a chassis to pass it through the screening equipment is also an extra step in moving freight within the yard. The air quality requirements in Southern California requiring biodiesel fuel can be problematic for terminal operators as they and their partners in the supply chain, e.g., vessel operators and truck drivers, strive to come into compliance.

4.2.3.3 Physical Constraints

Physical capacity at the port terminals is of the least concern of the three constraint types. The following physical constraints were identified:

- Access to streets and highways outside the gate
- Terminal layout land access
- Barriers to rail efficiency
- Wharf conditions
- Gate configurations
- Lack of channel depth.

On the inland waterways, physical capacity is frequently restricted by weather conditions including fog.

Using delay as an indication of mobility constraint, the respondents noted that the longest delays occur at the marine terminals. The wharves and the approaches to the (inland waterway) waterside were also identified as choke points in marine freight mobility.

The respondents representing deepwater ports and inland waterways identified the following physical freight mobility constraints that are often encountered:

- Inadequate terminal capacity
- Physical barriers to rail operations
- Empty container storage and movement
- Inadequate local street and highway access from terminal
- Inadequate waterway or channel depths
- Inefficient terminal layout.

These are ranked in decreasing order of occurrence.

Among the potential operational constraints, Transportation Worker Identification Credential (TWIC) requirements were identified by only a few respondents (less than 30 percent) as having an impact on freight mobility. Each port is unique in terms of configuration and operation. Therefore improvements that may be effective in addressing mobility constraints at one port may not necessarily be effective at another location.

4.2.4 Labor Unions

The labor unions across all modes agreed that any factor that defeats optimization of operations and causes delay is a "freight mobility constraint." The framework within which the management and labor relationship is structured varies from mode to mode dependent on historical, legal, and modal operational requirements. However, contractual terms of labor agreements are noted to be major constraints. In general, labor faces operational and physical constraints more than regulatory ones. The following are cross-cutting commonalities among labor unions.

4.2.4.1 Physical Constraints

Insufficient Infrastructure Capacity. Motor carriers, railroad workers, waterways labor, lock and dam operators, and longshore clerks and checkers all indicated the lack of sufficient capacity to move cargo efficiently through their systems as a major constraint. Channel conditions at deepwater ports and along inland waterways must be deep enough so that vessels can pass safely while heavily laden with containerized or bulk cargo. The lack of sufficient clearances and channel width at deepwater ports not only is a freight mobility constraint but also has safety implications.

Lack of Maintenance of Existing Equipment and Facilities. Scheduling equipment outages for maintenance can cause backups across all modes. Roadways, railroads, port terminals, locks and dams, and waterways terminals routinely experience some maintenance cycle shutdowns. Better planning and coordination across modes and involving labor in the planning would improve the situation.

4.2.4.2 Operational Constraints

Labor Utilization. The labor unions have special concerns with how some current contractual requirements impede efficient crew utilization. For example, the problems with excess "limbo time"; that is, the time used up by rail workers after they have completed a 12-hour shift to wait for transport to their home base and for which they are not compensated. Greater labor-management collaboration and increased accountability could eliminate the problems of "limbo time" and stranded crews.

Labor Supply and Training. There has been shortages in experienced labor supply particularly for inland waterway operations. The Federal employees who operate the nation's locks and dams are experiencing retirement of older, seasoned personnel with pressure from the Department of Defense (DOD) to contract out their work rather than to hire and train Federal employees.

Union specialist lock operators and mechanics are frequently on single-person shifts to operate the facilities and must have expertise in the total operational facility as they are the first responders to any difficulties at the facilities. The union representing these workers has worked with management at the local level to counteract contracting out to inexperienced workers.

The Teamsters have responded to mobility constraints by allowing motor carriers more flexible use of Teamster drivers. For example, the Teamsters now allow companies to put empty trailers on rail equipment, whereas before, the contract required motor carriers to use road drivers to do so. Also, to reduce travel during peak congestion times, the union strongly advocates that trucking companies and their customers allow evening and weekend deliveries.

Productivity and Use of Technical Tools. Technical tools are being developed within all modes to facilitate greater productivity of people and equipment. The labor unions have supported these moves particularly as it improves other concerns such as labor allocation pools that must respond to daily or weekly changes in demand; operational communication processes between labor and management; business transaction paperwork that labor is responsible to complete; and facilitation of safety in the field with electronic warning systems. Unfortunately, their successes depend upon the accuracy of the information communicated among the participants in managing the goods movement process and in warning of system delays. The railroads are working with the Federal government to devise new safety warning systems and are developing communications systems that can operate in "blackout" areas. The clerks and checkers at deepwater port terminals are being trained in the new computer systems and it is expected that as younger members join the workforce, they will reflect their generation's use of computer skills and technical tools.

Management-Labor Communications. The challenge of addressing goods movement constraints and resulting delays involves multiple variables frequently including a lack of communication to involve those in the field with those who are making decisions that affect them. Labor unions work cooperatively with management to varying degrees. The legacy contractual and once-regulated modal relationships can impede discussions of ways to resolve problems. On the other hand, the cooperative efforts of longshoremen and seafarers to work with management in meeting the needs of critical national demands to keep cargo flowing through our nation's ports and waterways has reduced risks and shared the costs of training. Communication among goods movement partners, labor, and management appear to be gaining a foothold in the most recent contract negotiations.

4.2.4.3 Regulatory Constraints

Several of the unions cited the new DHS requirements for all modal workers to have a TWIC as a problem. These concerns include the fact that monitors are not yet in place to read the electronic identification cards and so labor must be used to check these cards for persons entering and leaving transportation facilities such as port terminals. Such persons include railroad workers who are not yet sure if the railroads will cover the cost of their cards or if the railroads will place the burden upon the ports to escort non-TWIC-carded individuals into and out of the port.

4.2.5 Summary

4.2.5.1 Causes of Constraints

The survey results clearly indicate that overall, DHS security requirements do not significantly impede freight movements by highway and rail. However, deepwater port, inland waterway, and labor union respondents indicate that DHS security requirements somewhat impede efficient freight movements (Figure 13).

More than 65 percent of respondents indicate that Federal, state, and local land use and environmental regulations impede efficient freight operations to noticeable extents. As noted in Figure 14, these regulations appear to affect freight movements through the deepwater ports more than by rail and highway. Land use restrictions inhibit provision of parking facilities particularly in urban areas, thus constraining mobility of freight vehicles on the highway system.

Federal and state safety regulations are noted to impede efficient freight operations to noticeable extents by all modes, as shown in Figure 14. With regards to land use and environmental regulations, freight movements through deepwater ports and by inland waterways are shown to be impacted more than movements by rail and highway (Figure 15). In general, Federal and state regulatory requirements, including safety, security, environmental, and land use do impede freight mobility to noticeable extents.

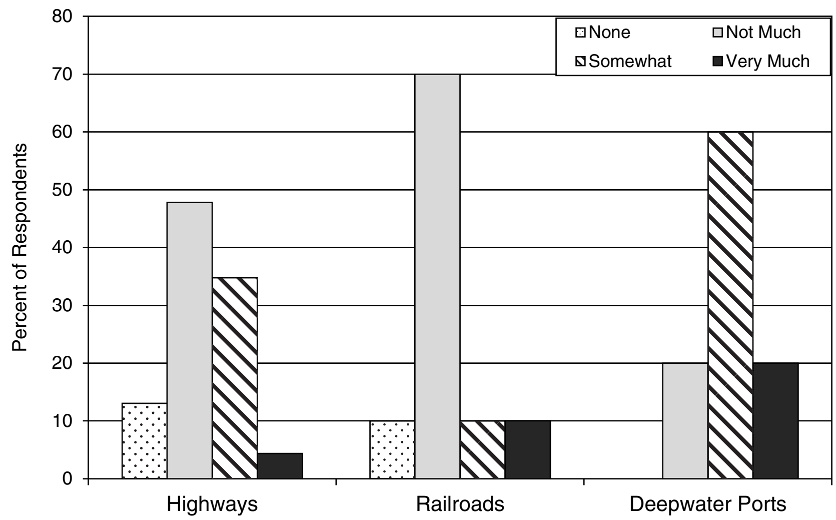


Figure 13. Impact of DHS requirements.

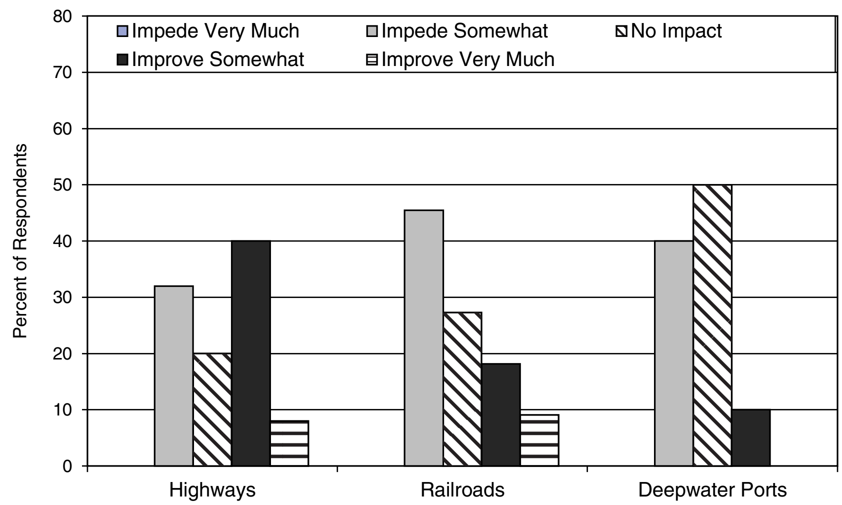


Figure 14. Effects of Federal and state safety regulations.

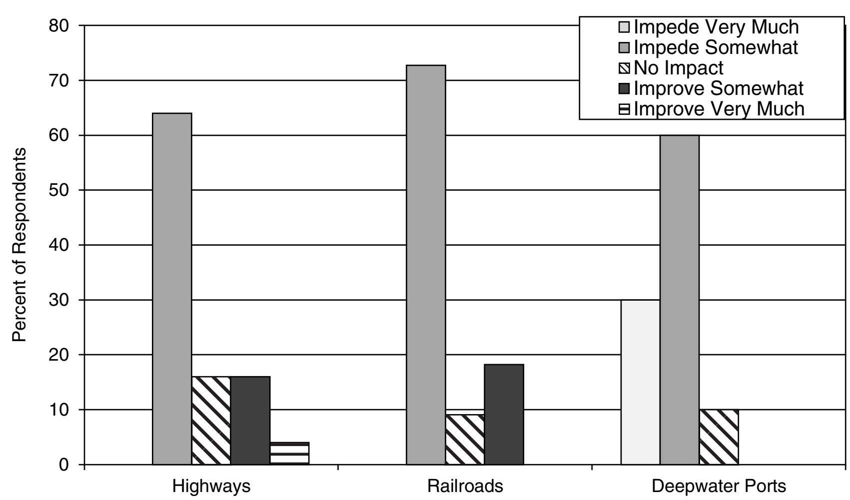


Figure 15. Effects of land use and environmental regulations.

From the motor carriers' perspective, the top three policy- or regulatory-related issues that have the most significant impact on freight mobility are:

1. Inadequate truck parking (determined by land use control)
2. Hours-of-Service regulations (safety regulation)
3. Speed limit differentials between cars and trucks (safety consideration).

4.2.5.2 Major Constraint Types

The predominant type of freight mobility constraint depends on the primary mode of freight movement. Figure 16 shows the ranking of the five categories of constraints by modal operators. Technological limitations or inadequacies were separated from other operational constraints in order to better understand how technology can improve freight mobility. It is clear from Figure 16 that technology is a significant factor in freight mobility by all modes. Similarly, financial limitations are important detractors to improved freight mobility. Also, regulatory requirements are considered to be major constraints affecting freight movement by all modes.

For the motor carrier industry, however, operational limitations are the topmost constraints. Physical or infrastructure deficiencies are not considered the most critical constraints affecting freight mobility. Physical infrastructures are fixed assets that oftentimes may require major expenditures to expand their capacities. Therefore, for a given transportation infrastructure system, it would be expected that optimal operations can be achieved through operational and regulatory improvements.

Respondents across all modes (excluding motor carriers) indicated that lack of skilled labor (including drivers, crews, etc.) is the most common operational impact of freight mobility constraints.

4.3 Measures or Indicators of Mobility Constraint

The performance measures used in monitoring and identifying freight mobility constraints vary by mode and agency. In terms of public- and private-sector perspectives, especially for highways, the performance indicators are different. State DOTs and MPOs present the public-sector perspectives for the highway mode and the motor carriers present the private-sector perspectives. Public-sector agencies implement improvements to address constraints to facilitate safe, secure, and efficient movement of freight. The private sector, on the other hand, uses different measures to monitor and identify constraints to their operations and reacts by taking measures that minimize the effects of constraints on the safe, secure, and efficient movement of freight. The following sections discuss the measures for highways, railroads, deepwater ports, and inland waterways.

4.3.1 Highways

In general, state transportation agencies do not have a well-defined set of measures or indicators for freight mobility constraints. There are no defined thresholds such as those that agencies use for other system-adequacy criteria. Typical highway agency criteria often considered when selecting projects include volume/capacity (v/c) ratios greater than 0.9, present

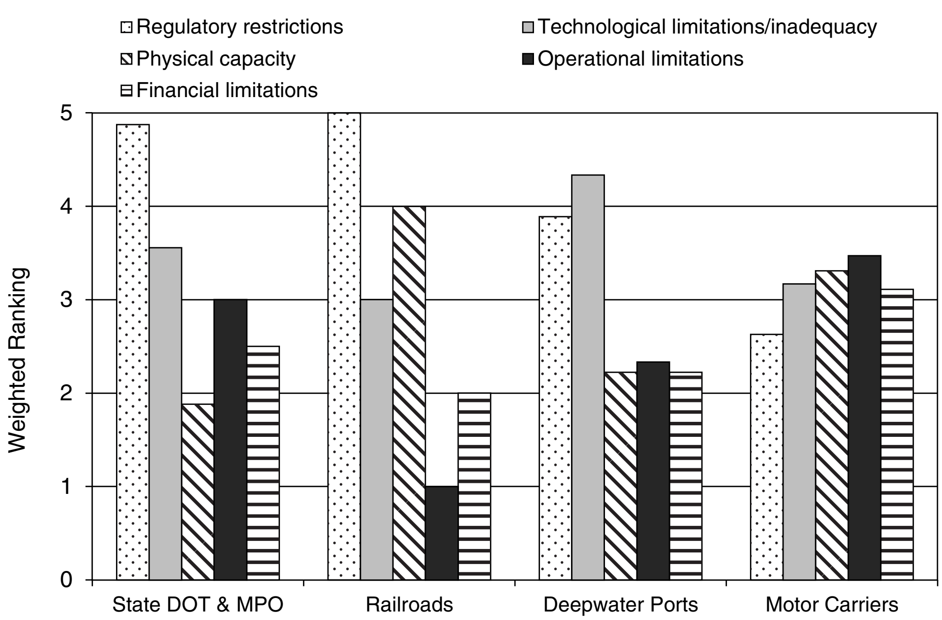


Figure 16. Ranking of constraint types by mode.

serviceability index (PSI) ratings below 3, or structural deficiency rating of a bridge below 5.

Some implicit measures or indicators exist in the states where freight programs select projects. The criteria by which they select projects to enhance freight mobility are de facto indicators of freight congestion. For instance, Oregon DOT measures a proposed project's ability to alleviate a freight mobility constraint according to whether a proposed transportation project:

- Reduces transportation costs for Oregon businesses or improves access to jobs and sources of labor
- Results in an economic benefit to the state
- Is a critical link connecting elements of Oregon's transportation system that will measurably improve utilization and efficiency of the system.

Proposed projects are scored by teams of DOT and outside officials to determine which submitted projects best meet the stated goals.

Florida's Strategic Intermodal System Highway Connector (*83*) projects are selected based on the relative severity of factors such as Annual Average Daily Traffic (AADT), v/c ratios, and the amount of economic activity occurring near a proposed location. Growing congestion, combined with the facility's role of providing access to an important freight generator, becomes one of the criteria used to select it as a freight mobility project.

Utah DOT (*84*) uses a set of criteria in identifying its low-cost, quickly implementable freeway improvement projects. The projects are not specifically freight improvement projects. They are general highway improvement projects, but they help freight because of the high volumes of trucks on Utah highways. Trucks compose up to 55 percent of total traffic volumes on the state's Interstate highway system. Utah DOT qualitatively selects possible locations for improvement based on recommendations from staff, which include factors such as observed congestion, the lack of environmental or right-of-way constraints, the rapidity of implementation, and the relatively low cost of the proposed improvement. A quantitative ranking is then applied to the proposed projects based on the following criteria:

- Average daily traffic
- Volume-to-capacity ratio
- Crash history.

The Ohio DOT (*85*) selects its major new capacity projects through the Transportation Review Advisory Council. The Council has adopted formal criteria by which it ranks projects. The highest ranked projects are given preference for selection once overriding impediments such as excessive cost, environmental constraints, or a lack of community support are considered. In other words, the criteria are not the sole factors in selecting projects but they play a significant role in ranking candidate projects. The factors used by Ohio DOT have at least three criteria directly related to freight mobility. The total factors include:

- AADT
- AADTT
- Volume-to-capacity ratio
- Whether the project completes a gap on a statewide economic corridor
- Crash history
- Connectivity to other modes.

The criteria of AADT, corridor completion, and intermodal connectivity all tend to benefit freight-heavy projects. The intention behind these criteria is to improve freight mobility to enhance the state's economic competitiveness. Beyond these implied indicators of mobility constraint, the agency officials across all states in the survey cited what they consider to be general indicators of freight mobility constraints:

- Comments from freight industry members about the congestion they experience at locations such as steep grades, congested intersections, and inadequate interchanges
- Poor turning radii at intersections and driveways
- Queues of trucks at specific bottlenecks
- The lack of regulatory coordination between neighboring states in terms of truck inspection, enforcement, and regulation
- Decreases in observed operating speeds
- Decreases in reliability as measured by travel time variability.

The FHWA Office of Freight Management and Operations sponsors the Freight Performance Measures (FPM) initiative, which is managed by the ATRI. Under this initiative, wireless truck position reports from several hundred thousand trucks are collected and analyzed. As a component of the FPM research, ATRI analyzed a list of 30 significant U.S. freight bottlenecks that were previously identified by FHWA. Actual truck speeds for these bottlenecks were aggregated to determine the impact of congestion on average truck speeds over a 1-year timeframe. Based on these results, the original bottlenecks were re-ranked by severity. These are discussed in Chapter 7 of this report.

From the private-sector (i.e., motor carrier industry) perspective, motor carriers utilize several measures to monitor the efficiency of fleet operations, including customer-related performance metrics. Customer-related metrics include how often a carrier delivers or picks up on time, the service times to move freight from the point of origin to the final destination, or revenue per truck per day.

Fleet operations metrics include stops per driver (in metropolitan areas only) per day, the cost to provide service to an area, and the amount of time a driver is delayed. Other metrics focus on operational efficiency and equipment use and may include:

- Percentage of truck engine idle time
- Average speed per truck
- Truck utilization (miles per tractor per day)
- Billed versus unbilled miles (indicator of out-of-route miles or non-revenue-generating miles).

Other measures used by carriers to monitor the impact of mobility constraints on performance are driver stress (congestion is a significant factor leading to driver stress) and driver retention/turnover rates, typically higher in heavily congested areas.

4.3.2 Railroads

The following rail industry metrics are used to gauge performance and to indicate mobility constraints:

1. **Train speed**—measures the line-haul movement between terminals. The average speed is calculated by dividing train-miles by total hours operated, excluding yard and local trains, passenger trains, maintenance of way trains, and terminal time. Train speed is a good measure of mobility; however, data on train speed are not readily available except at aggregate levels.
2. **Terminal dwell time**—is the average time a car resides at the specified terminal location expressed in hours. Dwell time measures delay and indicates mobility problems. However, data on dwell time are not generally available and may be difficult to interpret for low-cost improvement projects.
3. **Safety**—the most important performance objective, for most respondents. Whereas this measure does not indicate mobility, performance is used to gauge freight mobility.
4. **Customer service**—customer satisfaction is the second most often used metric and one of the most important management performance objectives. In addition, railroads sometimes use percentage of on-time arrivals, car cycle times, and cars moving on correct trains as customer service metrics to measure performance.
5. **Financial results**—take various forms, such as measurement of the precursor operating ratio (expenses divided by revenue) or, for public companies, earnings per share or stock price. Some of the suggested metrics (velocity, customer satisfaction, revenue growth) are drivers of financial performance, while stock price is a derivative.

4.3.3 Deepwater Ports and Inland Waterways

Several indicators were noted to be of importance to processes and to overall supply chain costs and operations for ports:

- Traffic volume demand and response cycle monitoring to adequately plan for and handle surges, clogs, dead times.
- On-time arrival percentage of time for ships, labor, trucks, and rail.
- Dwell time in days, i.e., the number of days the cargo sits in the terminal.
- Overall supply chain transportation velocity because uneven freight velocity is the key indicator for goods requiring synchronization and controlled integration into manufacturing or retail streams. As one respondent stated, “low freight velocity is the key indicator for high-value retail goods, but it is difficult to quantify or identify as it (the supply chain) encompasses many players, routes, modes, and transfer points.”
- Available competitive transportation options, because the customer is looking for the cheapest route from origin to destination. Competition can be as simple as the number of rail lines serving one port or the shipping by rail costs at one port in the United States and one port in Canada. One respondent cited the fact that rail rates are currently $400/box cheaper at a port in Canada and are far cheaper than those rail rates charged in a nearby U.S. port. The U.S. port customers are moving discretionary cargo to Canada to take advantage of the cheaper rail rates.
- Cost volatility related to suddenly increasing costs, e.g., fuel, insurance, security requirements.
- Customer satisfaction, as unhappy customers due to delays or lapses in pickup and other terminal operator responsibilities can mean a loss of customers.
- Labor supply or enough trained workers who are available when needed and are stable without unrest and threats of strikes for higher pay.

4.3.4 Summary

Figure 17 shows the ranking of the performance measures in decreasing order of use in monitoring freight mobility systems

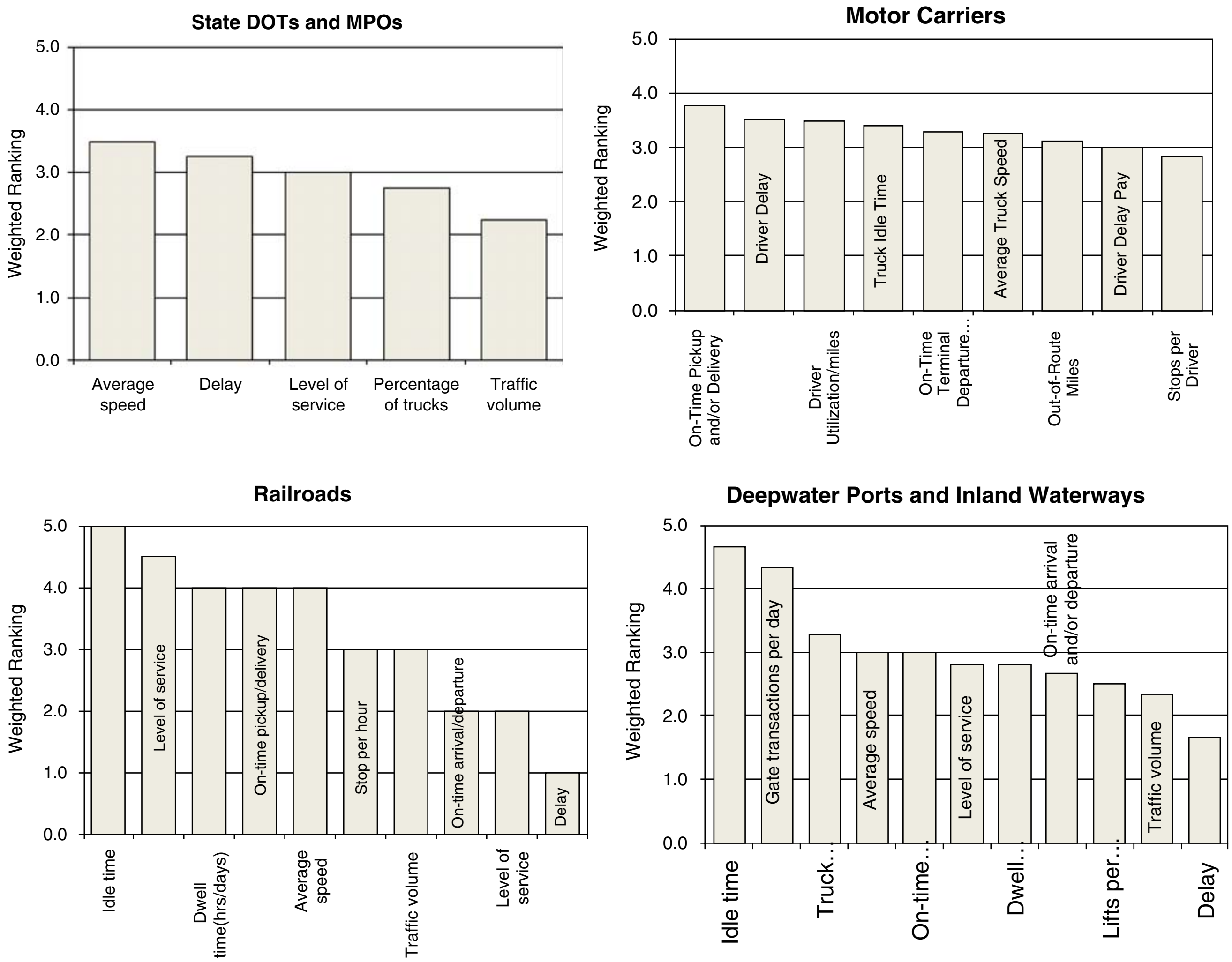


Figure 17. Ranking of performance indicators.

and in identifying constraints. The performance measures vary by mode but there are some similarities between rail and deepwater. For freight movement by highway mode, delay is a common measure used by both the public and private sectors in monitoring and identifying freight mobility constraints. For rail and deepwater ports, on the other hand, idle time is most commonly used, while delay is seldom used to monitor and identify constraints.

Table 22 summarizes the major causes of freight mobility constraint by mode and shows the top ranked performance measures. Table 23 presents examples of freight mobility constraints by type (physical, operational, and regulatory) and by mode from public- and private-sector perspectives.

The next chapter develops the criteria for low-cost and quickly implementable improvements to address the freight mobility constraints discussed in this chapter.

Table 22. Primary causes of mobility constraints by mode.

Mode	Primary Causes	Metrics/Indicators
Highways	• Regulatory constraints • Land use controls and regulations • Parking restrictions • Speed limits • Safety regulations • Hours-of-service regulations; • Highway geometry (e.g., outdated interchange and intersection designs to meet traffic demand and requirements of longer trucks; roundabouts near freight facilities) • Inadequate system management including outdated/inadequate traffic signal systems • Inadequate capacity to meet increasing demands • Poor road signage including warning signs	State DOTs and MPOs • Average truck speed • Delay to traffic • Level of service • Average daily traffic/truck traffic including percentage of trucks • Truck trips per day Motor carriers • On-time customer pickup/delivery • Driver delay • Driver utilization/mile • Truck idle time • Average truck speed
Railroads	• Regulatory constraints (Federal and state) • Inadequate physical capacity • Constrained capital budget • Lack of skilled labor • Poorly structured labor work rules	• Idle time • Average train speed • Level of service • Terminal dwell time • On-time customer pick-up and/or delivery
Deepwater port and inland waterways	• Regulatory constraints (e.g., land use controls and regulations) • Inadequate capacity of intermodal connectors (truck and rail) • Inadequate traffic system management on intermodal connectors • Terminal gate operating hours • Port terminal processing requirements • Security and air quality regulations	• Idle time • Gate transactions per day • Truck trips per day • Average speed • On-time pick-up and/or delivery • Level of service • Dwell time in hours or days

Table 23. Common mobility constraints by mode.

Mode	Physical Constraints	Operational Constraints	Regulatory Constraints
Highways	Inadequate mainline capacity – inadequate number of lanes Narrow roadway or lanes	Inadequate traveler information – Lack of timely traveler information on incidents, weather, temporary road closures, construction zones	Parking restrictions Truck lane restrictions Speed limit restrictions
	Inadequate turning intersection radii and/or channelized turns	Poor road signage	Route restrictions for long combination vehicle and other trucks
	Inadequate weaving sections	Poor signal phasing	Land use controls and regulations
	Long, steep grades with no passing lanes	Lack of warning signs on crossroad approaches	DHS and other security requirements
	Short interchange ramps	Lack of 24/7 access to intermodal facilities	Hours-of-service regulations
	No turning lanes at intersections	On-street parking, bus or other roadside activities too close to intersections	Lack of interoperability in use of toll passes
	Insufficient parking for trucks	Inadequate loading zones	Differences in truck size and weight regulations
	Lack of alternate routes for large trucks	Lack of drivers	Lack of reciprocity in truck licensing and inspection
Railroads	Mainline throughput capacity	Signaling restrictions or less than optimal signaling – outdated/inefficient signaling & telecommunications	Federal and state regulations
	Inadequate sidings length	Terminals switching efficiency	Labor issues – supply, training, and utilization
	No passing siding	Inadequate investments in locomotives and freight cars	Lack of funding
		Speed restrictions in urban areas	
		Lack of skilled labor	
Deepwater port and inland waterways	Inefficient terminal layout/terminal gate configurations	Lack of labor /crew supply	Labor unions and contractual limitations
	Inadequate capacity of intermodal connectors	Lack of truck appointment pickup and dropoff systems	Restrictive security requirements
	Small, aging, unreliable locks (lock capacity)	Restricted terminal gate operating hours	Restrictive air quality requirements
	Lack of channel depth	Inefficient terminal layout	
	Flooding and insufficient clearance (inland waterways)	Lack of electronic communication in rural areas (inland waterways)	

CHAPTER 5

Low-Cost, Quickly Implementable Improvements

This chapter defines the criteria for low-cost and quickly implementable improvements to address freight mobility constraints and presents strategies for addressing them. Information presented in this chapter is based primarily on the results of the stakeholder interviews and surveys. This chapter also presents examples of low-cost, quickly implementable improvements aligned with the freight mobility constraints by mode.

5.1 Definition of Low-Cost, Quickly Implementable Improvements

An important element in determining low-cost and quickly implementable strategies to mitigate mobility constraints is to determine how stakeholders vary in their definition of low-cost and quickly implementable improvements. The following sections discuss the modal definitions and summarize the characteristics of low-cost improvements followed by a generalized definition with caveats for each mode.

5.1.1 Highways

The agencies interviewed differ significantly when defining what would constitute a low-cost or quickly implementable project. In general, a low-cost and quickly implementable improvement could be defined as one that does not require special programming, does not require right-of-way acquisition, and is within budget limitations enabling implementation at a district level. The consensus was that a low-cost improvement project should be on the order of $1 million or less, and "quickly implementable" was considered to be 1 year or less. To contrast, most agreed that a project requiring an investment of $10 million was a fairly major effort.

Some specific examples of the definitions are presented below:

- Oregon DOT has a specific program that targets low-cost, quickly implementable freight projects. The program rewards projects that could be implemented in one to three construction seasons. Such projects tend to have smaller right-of-way footprints, lack significant environmental impacts, have community support, and are unlikely to be delayed by other project development factors. "Low cost" is defined as being between $50,000 and $2 million. "Quickly implementable" includes projects that can be built within 3 years.
- New Jersey DOT has a program called Fast Moves, which funds projects of up to $10 million. It does not have specific thresholds for "quickly implementable" or "low cost," but it considers Fast Moves projects to be so because they generally lack extensive right-of-way or environmental complexities. Costs range from less than $2 million to more than $10 million.
- California DOT (Caltrans) has not developed a formal definition of a low-cost freight mobility project. However, a low-cost project may only address certain elements of a problem or alleviate the congestion for a few years. Low-cost projects may be more associated with an initial project phase than with a particular strategy or program for building an entire low-cost freight mobility project.
- Ohio DOT produced more than 700 quickly implementable and low-cost projects when it began an intensive and focused safety program in the mid-2000s. The projects were driven exclusively by safety and not by freight mobility. Projects included basic improvements such as enhanced lane markings to delineate through lanes in areas of "lane drops." Pavement with poor friction was treated with thin overlays in areas where rear-end crashes were common. Lighting and signage were improved.

Outside of these specific programs, the personnel who were interviewed across all responding agencies gave wide ranges in their personal descriptions of what are "low cost" and "quickly implementable." Officials who were accustomed to addressing deficient system interchanges indicated that "low cost" could be as high as $20 million. A project of $20 million that addressed a freeway bottleneck was considered “low cost” in comparison to the much larger total highway program. Others said low-cost projects would be in the $50,000 to $250,000 range. The respondents’ perspectives appear to vary with their position. Operations personnel tended to cite lower thresholds for “low cost.” Respondents accustomed to working with larger capital programs tended to define “low cost” considerably higher, up to $20 million.

Similar perspectives were given to the definition of “quickly implementable.” One respondent categorized “quickly implementable” as being any strategy that an agency can adopt administratively, without seeking approval from outside agencies. When outside agency approval is needed, it generally indicates that the project has some impacts and will result in more lengthy reviews.

5.1.2 Railroads

The definition of a “low-cost” and “quickly implementable” improvement project varies depending on the category of the railroad. For a regional railroad, a “low-cost” improvement project is one that is less than $500,000 while “quickly implementable” would be completion in under 6 months. For a short-line railroad of modest size, projects that cost less than $2 million and that could be completed in 2 years would fit the criteria. A major Class I railroad, on the other hand, thought the cost range might be more like $1 million to $10 million.

Ideally, a low-cost and quickly implementable improvement project is one with a cash payback within the current year—so that there would be no impact on net income. This criterion would also allow a line manager to use an authorized operating budget to complete a “capital” project outside of the firm’s annual capital expenditures budget and thus speed up realization of the project benefits. Most railroads prepare capital budgets midway through the year, effective the following January 1, and thus there is a minimum 6-month delay in implementing a new capital project. Also, amendment of capital budgets to accommodate new projects is infrequent at railroads with tight cash flow constraints. However, the current year payback scenario represents unusual circumstances, as few projects yield returns this high and this fast. Also, most railroads probably would frown on going outside established capital budgeting guidelines in this manner.

While most projects of the low-cost and quickly implementable size can be completed in a single construction season, to do so requires advance preparation and coordinated scheduling. On large railroads with dense traffic, moreover, the specific constraint is likely to be “track time,” i.e., the “window” in train schedules for maintenance of way (MOW) work, rather than total elapsed time. Railroads make great efforts to schedule availability or delivery of all the needed resources (labor, materials, track construction machinery) around train schedules to minimize disruption to trains and specifically to customer commitments. It is not unusual for railroads to work with major customers on track improvement projects – for example, by coordinating track work with a factory slowdown for vacations or heavy maintenance. Given the state of short-line infrastructure, the issue is not whether projects are inexpensive and can be implemented quickly, but how they can be financed.

5.1.3 Deepwater Ports and Inland Waterways

Low-cost physical improvements to reduce port congestion and enhance landside freight movement are similar to those for the primary modes linking the intermodal facilities. Examples include improving the turning radii and lanes for intermodal connectors and adding rail spurs and tracks serving the ports. Operational improvements include port peak pricing strategies that use pricing to encourage pickup/delivery of cargo at less congested times so as to reduce freight and passenger congestion on the transportation system, improve operating efficiencies, and reduce truck wait and idling times, among others.

Interviews with port terminal operators indicate that given the complexity of their operations, and noting that the major mobility constraints are regulatory and operational in nature, no “low-cost” and “quickly implementable” action could be identified. However, from a private-sector point of view, any regulatory requirements that positively impact their operations could be viewed as low cost. Also, given that intermodal connectors are critical elements in the efficient movement of freight through the ports, any improvements that remove mobility constraints are reflected in the efficiency of operations of the port terminals.

A “low-cost” improvement in the inland waterways would involve better scheduling of and allowing transit of waterborne cargo according to two factors: (i) urgency of need for the cargo and (ii) resulting financial impact to the stakeholder of delay. Specific ideas included:

- Resource optimization instead of addition
- Not re-inspecting cargo that was already inspected at a foreign port terminal
- Using the arbitration system favored by unions to discuss greater use of optical readers at gates that would result in clerk reductions; also discuss flexible shifts this way.

Results of the survey indicate that overall, 43 percent of the respondents defined “quickly implementable” as improvements that can be completed in less than 1 year and another 35 percent of respondents indicated less than 2 years. The results strongly suggest that a quickly implementable, low-cost improvement project should be completed in less than 1 year

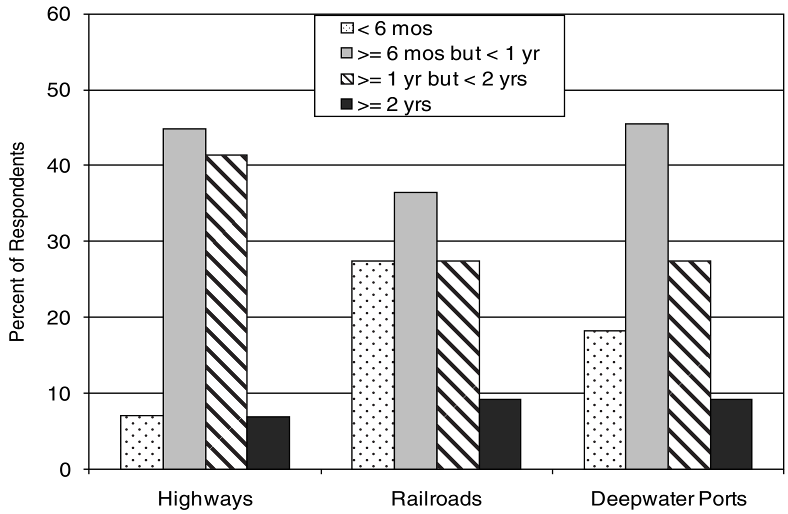


Figure 18. Definition of "quickly implementable."

(see Figure 18). The following section presents generic definitions of quickly implementable low-cost improvements.

5.2 Criteria for Low-Cost Improvements

Based on discussions presented above, the following paragraph presents generic criteria for low-cost, quickly implementable improvements and is followed by mode-specific definitions. Table 24 summarizes key characteristics of these improvements.

A "low-cost and quickly implementable" improvement to address freight mobility constraints may be defined as an action that modifies existing geometry and operational features of the freight transportation infrastructure system and that can be implemented within a short period without extended disruption to traffic flow. Such an improvement may be physical, operational, or regulatory, as long as it enables greater throughput from existing facilities. These actions may be spot (or location-specific) improvements or may be limited to short sections of the physical infrastructure. Likewise, they may be specific to a given supply chain process point, regulation, or mode; they may also be multimodal. Furthermore, low-cost improvements do not involve massive reconstruction of infrastructure that usually takes many years to complete.

Highways: A low-cost and quickly implementable improvement does not require special programming, time-consuming environmental clearances, or right-of-way acquisition and are within budget limitations enabling implementation at a district

Table 24. Key features of low-cost and quickly implementable improvements.

Mode	Characteristics of Low-Cost Actions	Quickly Implementable
Highways	• Less than $1 million • Spot or location-specific improvements • No environmental clearances necessary • No right-of-way acquisition • No special programming required • Implementation at district lowest operation unit level (limited direct HQ oversight)	Less than 1 year
Railroads	• Class I railroad – $1 million to $10 million	Less than 2 years
	• Regional railroad – less than $2 million	Less than 1 year
	• Short-line railroad – less than $500,000	Less than 6 months
Deepwater Ports & Inland Waterways	• Less than $1million • Physical improvements may involve highway and rail projects within and outside the port terminals at links serving ports – location-specific actions • Mainly operational actions including technology deployments • Uniqueness of each port acknowledged	Less than 2 years

level. A low-cost improvement project is generally considered to cost $1 million or less, and a quickly implementable project is to take 1 year or less to complete.

Railroads: The definition of a low-cost and quickly implementable improvement project varies depending on the category of the railroad. For a short-line railroad, a low-cost improvement project is one that is less than $500,000 while a quickly implementable project would be completed in less than 6 months. For a regional railroad of modest size, projects that cost less than $2 million and that could be completed in 2 years would fit the criteria. A major Class I railroad, on the other hand, thought the cost range might be more like $1 million to $10 million. Right-of-way acquisition almost always delays a project and eliminates it from the low-cost category.

Deepwater Ports and Inland Waterways: Low-cost operational improvements are typically economic-incentive–based programs that influence demand, lead to changes in operations and processes (including the use of advanced technologies), and encourage modal shift. Low-cost physical improvements to reduce existing and potential port congestion and enhance landside freight movement may need to be coordinated with highway and rail improvements both within and outside the terminal. These improvements facilitate intermodal activities, e.g., restriping and signal timing changes at intersections leading to port terminals and improvements of rail tracks and switches. A low-cost and quickly implementable improvement for both deepwater ports and inland waterways would cost up to $1 million and require up to 2 years for implementation.

5.3 Characterization of Improvements

The type of improvement is not determined by the type of constraint. Operational improvements can be used to address physical constraints and vice versa. Similarly, regulatory and policy actions can be implemented to remove operational and physical constraints. Consistent with the type of constraint, the three main types of improvements are defined below. Policy-type improvements are considered under the regulatory type, while economic-based actions that affect price and market-based solutions are classified as operational improvements. These definitions are generic, and while physical improvements are quite distinct, certain types of improvements could fit either regulatory or operational categories. The grouping or labeling is less important than the actual strategy or action itself.

5.3.1 Physical Improvements

Physical improvements involve construction activities to improve geometry or add capacity by adding more usable space. Examples include extensions to rail sidings to allow longer trains, addition of turning lanes at intersections, and addition of space to increase terminal capacity.

5.3.2 Operational Improvements

Operational improvements are directed at reducing occurrences of conflicts and delays to processes and traffic through the implementation of technology, changes in operational schedules, and sequences. Examples include use of intelligent transportation systems to provide traveler information, changes in signal phasing at intersections, congestion pricing to control demand, use of economic-incentive strategies to control demand, and use of centralized train control systems.

5.3.3 Regulatory Improvements

Regulatory improvements entail the institution, relaxation, or modification of regulations, policies, and actions that improve freight mobility on the transportation system. These improvements include labor agreements, technology standards, and stakeholder partnerships directed at improving cooperation among modes and among public and private stakeholders for the primary goal of improving freight mobility. Examples include relaxation or modification of regulations governing the operating hours of freight vehicles especially in central business districts during peak hours, changes in land use and zoning laws to provide more parking for freight vehicles, and land border crossing requirements and controls.

5.4 Low-Cost Strategies for Addressing Mobility Constraints

This section discusses improvement strategies that have been deployed by public agencies and private stakeholders to address and mitigate freight mobility constraints. These strategies are derived from the results of the interviews and surveys with representatives of public agencies and private stakeholders involved in freight movement. Also presented are the processes used and factors considered in selecting improvements.

5.4.1 Highways Improvement Strategies

Responses from public-sector representatives such as state DOT and MPO officials are separated from the private sector (e.g., trucking industry) in order to distinguish their perspectives on strategies to address freight mobility constraints.

5.4.1.1 Public-Sector Strategies

A wide variety of strategies are in use by the responding agencies to address freight mobility constraints in order to reduce congestion on the highway system. Examples of low-cost physical improvements include:

- Operational capacity improvements such as auxiliary lanes between interchanges to reduce weave movements
- Selected improvements at system interchanges to eliminate at-grade merges or inside merge conditions
- Location-specific arterial improvements such as improved turning radii, the addition of turn slots, or the consolidation of driveways to reduce conflict points
- Restriping the merge/diverge areas to better serve demand
- Shoulder usage, especially on interchange ramps
- Modifying weaving.

Table 25 compares the rankings of low-cost physical improvements as derived from results of the surveys. From the perspectives of the public sector (represented by state DOTs and MPOs) and the private sector (motor carriers), traffic signal synchronization and auxiliary lanes were ranked the most effective low-cost actions in improving freight mobility on the highway systems.

Traffic signal synchronization was considered an effective strategy but no example could be cited where it was applied specifically for a freight corridor. The economics of truck operation are such that minimizing braking and idling can produce substantial operating cost savings over time (as well as reductions in emissions) in addition to whatever time savings are garnered.

Whereas steep grades can be implemented more as a safety countermeasure, they can be mobility constraints especially where the truck volume is high. In such cases, the use of truck climbing lanes is effective in addressing the constraint.

It was noted that the basis for AASHTO design of acceleration and deceleration lanes is the passenger car. Motor carriers recommend that truck acceleration capabilities be part of highway geometric design criteria.

Different truck types are now being used with uncertain turning characteristics. Generally the view is that trucks are more maneuverable now (doubles and triples have lesser requirements). Offsetting light standards, signs, poles, and improving the turning radii at intersections with tight turns are effective improvements.

Traveler information including advance notification of work zones, closures, and detours for motor carriers was seen as very important to enhance mobility. Deployment and use of variable message signing with real-time information was viewed as valuable. Part of this problem involved notification of wide-load restrictions due to work zone configuration.

Stakeholders also identified the following specific low-cost operational and technological improvements to be potentially effective in addressing freight mobility constraints:

- Ramp metering and ramp closures
- Intersection "channelization" or lane improvements
- Signal timing coordination
- Various intelligent transportation system strategies such as variable message boards to alert traffic of incidents and to advise motorists to seek alternate routes
- Advisory radio broadcasts to motor carriers warning them of accidents, steep grades, sharp turns, or other locations of incidents that could cause delay or accidents
- "Quick clear" teams and policies to respond to accidents
- Programmatic maintenance of traffic practices during construction to reduce delay. These can include night construction, use of temporary lanes, and contractual incentives for contractors to complete work quickly.

One of the most mature and detailed operational approaches to freight congestion relief is taken by the I-95 Corridor Coalition (*86*). The Coalition offers extensive training in operational strategies such as "quick clear," and other practices to promote greater efficiency along the corridor. It encourages

Table 25. Top ranked improvements.

Public Sector (State DOTs and MPOs)	Private Sector (Motor Carriers)
1. Traffic signal synchronization	1. Traffic signal synchronization
2. Auxiliary lanes	2. Auxiliary lanes
3. Truck climbing lanes	3. Acceleration and deceleration lanes
4. Improved intersection turn radius	4. Truck climbing lanes
5. Truck restrictions	5. Restriping to add more lanes
6. Acceleration and deceleration lanes	6. Paved shoulders
7. Intersection turn lanes	7. Traveler information
8. Restriping to add more lanes	
9. Ramp metering	
10. Ramp widening	
11. Temporary ramp closure	
12. Traveler information	
13. Removal of vertical clearance impediments	
14. Paved shoulders	

agencies to work cooperatively to promote regional approaches intended to maximize the existing capacity in the corridor and to improve bottlenecks, whether they are physical, operational, or regulatory.

5.4.1.2 Methods and Approaches to Selecting Improvements

Data gathered from the survey of stakeholders indicate that state DOTs and MPOs use cost, availability of funding, and regulatory requirements as the main factors when considering a low-cost improvement action to address a mobility constraint (Figure 19). However, in comparing alternative potential improvements, historical information on past project performance and stakeholder/customer inputs (Figure 20) are the factors most often considered. The figure suggests that benefit-cost analysis is less often used in selecting improvement options.

Agencies use different strategies to select improvements but most depended upon both quantitative and qualitative considerations. In some cases, quantifiable factors were used to identify candidate projects which then were ranked by qualitative factors. In other cases, qualitative factors were used to identify potential actions which then were finally selected based upon quantitative scoring. The following examples illustrate the steps used by different agencies:

- In the greater Phoenix area, the Maricopa Association of Governments and Arizona DOT cooperate on the identification of locations where auxiliary lanes could be added to improve weave and merge conditions. The locations are selected upon "hard" factors such as traffic volumes and crash histories but also "soft" factors such as ease of implementation.
- In Florida, the identification of routes and facilities for inclusion on the Strategic Intermodal System is formally quantified. Range factors and thresholds are used, such as the volume of freight, number of flights, port volumes, and regional connectivity of corridors. Ranges and values are used to identify facilities and then to categorize them by importance. However, when individual actions are taken to improve those facilities, additional qualitative factors are considered. These include the importance given to the project by regional planning officials, speed with which the improvement can be implemented, perceived economic benefit, and the degree of local financial support.
- In Ohio, the identification of high-crash freeway locations was formal and quantified. The department sought out locations that had crashes well above the mean for a 3-year period. The department then analyzed crash locations by crash type such as rear-end, angle, or head-on to help identify countermeasures. Finally, the qualified judgment of engineers as to the speed of construction, cost, and effectiveness of the countermeasure was considered before finally selecting a project or action.
- Ohio followed a similar process for identifying high-congestion freeway locations. The top 250 high-congestion freeway locations were analyzed based upon traffic volumes and volume to capacity ratios. Candidate projects were then given qualitative assessments by engineers as to the feasibility of improvements considering factors such as cost, environmental constraints, or community sensibility. Projects that passed those quantitative and qualitative factors were then ranked by additional factors such as crash history, volumes, congestion, truck volumes, economic impact, and regional priority for the project.
- Oregon's ConnectOregon non-highway freight projects and its highway-focused Transportation Innovation and Operations Demonstration Program projects are solicited through public calls for applications. Formal applications are submitted and the data included in the applications are used for quantitative and qualitative ranking by independent panels.

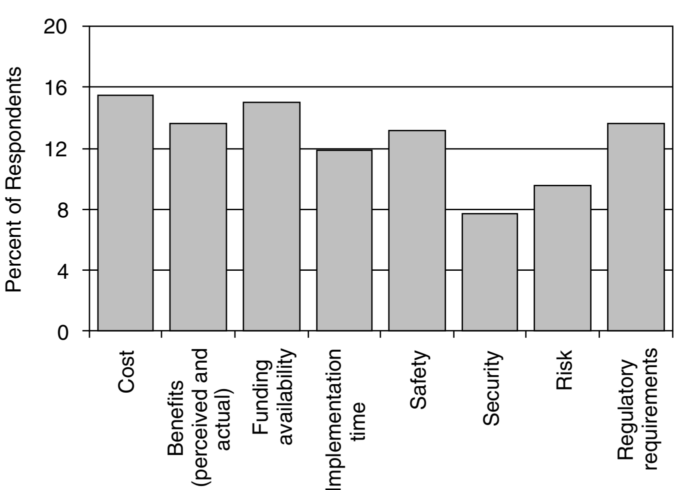


Figure 19. Factors for evaluating improvements.

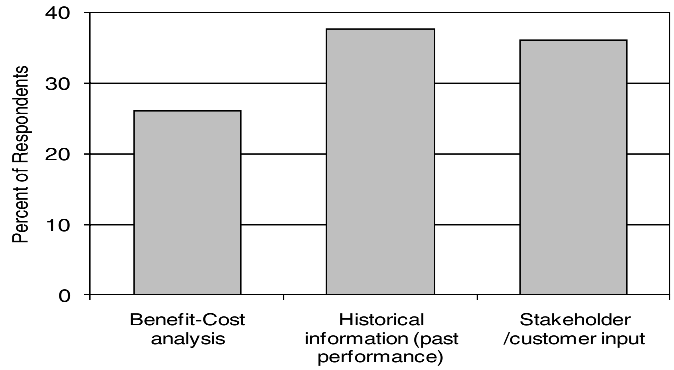


Figure 20. Steps in selecting improvements.

A strategy used by some organizations to respond to freight mobility constraints is to solicit input from freight stakeholders. The Maricopa Association of Governments formed a freight advisory group and invited a member of a prominent logistics firm to serve on its board. In Utah, the DOT's freight coordinator sought out trucking firms for group meetings in which they would review maps and share experiences in order to identify mobility constraints.

Caltrans has one of the largest freight mobility programs in the nation. Beginning in June 2004, the state began a concerted effort to assemble goods movement stakeholders. Those efforts led to the publication of a Goods Movement Policy (*87*). That, in turn, was followed by a $107 billion freight investment program, which focuses on highways, rail, and other freight infrastructure facilities. Complementary land use and environmental policies also were included in the program. Caltrans officials indicate that the program will result in significant capital investment but also will significantly increase the department's focus upon improved operations of the system. They note that modeling indicates that without the state's Strategic Growth Plan, congestion will rise by 35 percent. With the plan in place, congestion will rise nearly 19 percent. Even with the massive investment, congestion will grow and will require continued use of operational strategies.

Maryland DOT recently completed a Maryland Freight Profile, which is an extensive data set that delineates the freight system. From there they are developing a Maryland Statewide Freight Plan in conjunction with internal staff and outside freight stakeholders. Also in Maryland a Freight Project Needs Inventory has been drafted and will be further developed as the study continues. The Plan is designed to emphasize clear, achievable capital planning and outputs that can be implemented within 5-year and 25-year planning horizons. Outreach meetings to identify freight-system deficiencies and to recommend solutions are now under way. These meetings are being held across the state, and participation of both public and private stakeholders is encouraged.

5.4.1.3 Effectiveness of Improvements

The formal evaluation of project effectiveness is not common. From a freight effectiveness standpoint, no formal post-project evaluation processes were identified among the agencies interviewed. However data gathered from the surveys indicate that, for all three modes, stakeholders often use customer feedback and key performance indicators in assessing the success of improvements, as shown in Figure 21. Benefit-cost ratio is not routinely used to evaluate implemented projects, having been cited by fewer than 20 percent of respondents.

5.4.1.4 Private Sector Strategies

The survey results indicated that customer rebates or penalties for missed deliveries or pickups are common consequences of congestion or delay. The following are the main impacts of delay and congestion on customers:

- Some customers have expanded, adapted, or changed shipping/receiving hours at facilities.
- Cost of moving freight has increased due to congestion and delay.
- Customers have had to stop or delay manufacturing activities because goods are not received at a specific time due to congestion/delay.
- Customers have been displeased by late or missed deliveries.

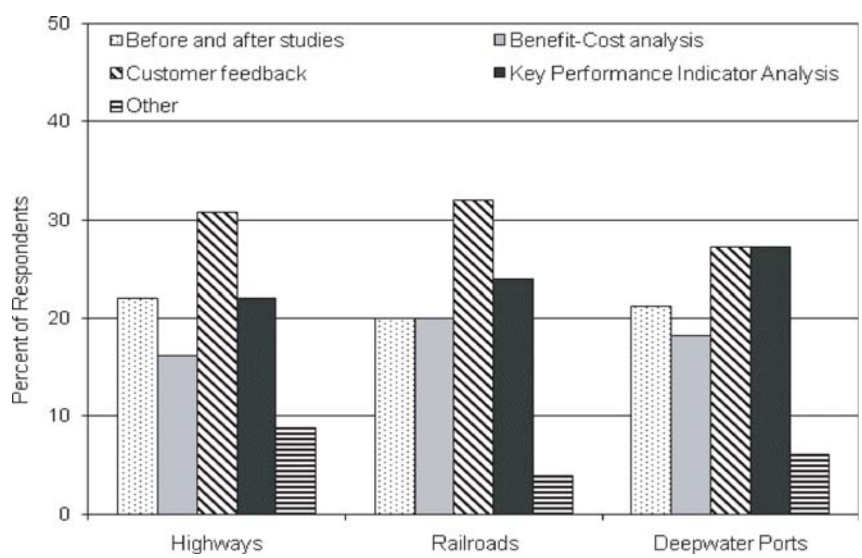


Figure 21. Assessing success of improvements.

The result of these impacts on shippers and distribution centers is a decrease in operating efficiencies and subsequent increases in both operating costs and transportation costs. For example, trucking firms and 3PLs have had to modify business practices to mitigate the impact of freight mobility constraints on their businesses. Furthermore, freight mobility constraints impact motor carrier operations in a number of ways. The most frequently reported consequences are:

- Increased operating costs
- Reduced revenue and equipment (e.g., tractor) utilization
- Increased difficulty positioning equipment and drivers
- Increased driver turnover in congested areas
- Higher pricing to offset increased costs
- Longer transit time
- Decreased levels of service.

The following actions are the top three specific actions often taken by motor carriers to reduce congestion and delay or to mitigate mobility constraints:

1. Use alternate routes to avoid congestion, which can result in trucks traveling on facilities that are not designed for heavy truck traffic, creating additional risks (including a lack of available safe locations where drivers can take breaks)
2. Reschedule trip/delivery
3. Deploy in-cab communication.

Other common strategies to mitigate these operational impacts include adding resources to maintain service levels such as drivers, tractors, trailers, terminals, and support personnel. In addition to adding resources, carriers must utilize existing resources in innovative ways. Examples include the use of lower cube equipment (i.e., smaller trucks) to access areas with physical constraints, the use of third parties or agents to make deliveries or pickups in severely congested areas, and a greater use of technology to monitor all aspects of fleet operations and costs.

Another innovation is the more flexible use of drivers. For example, respondents note local pickup and delivery routes are oftentimes a joint decision between management and drivers, with a strong emphasis on efforts to keep drivers on regular routes. There is also a growing trend of driver swaps and relays. Carriers also prefer to use team drivers for high-value loads to avoid unsafe routes or lack of adequate and secure parking facilities.

In response to carrier needs for more flexibility of driver use, recent labor contracts now allow carriers to use "hybrid" drivers, a type of driver that may be used for line-haul or local pickup and delivery. Other actions taken by carriers to mitigate mobility constraints include:

- Higher pay for drivers operating in congested areas
- More off-peak period operations
- Earlier truck departure times and later arrival times
- Adding terminals to cover smaller service areas
- Carrier-imposed restrictions on the movement of high-value shipments
- Facilitation of data exchange with shippers on the availability of loads and preclearance for pickups or deliveries
- A greater propensity to operate less than full trucks
- Additional charges for pickups and deliveries in congested areas or facilities.

More than half of the fleets surveyed (60 percent) indicated that customers have not assisted in mitigating the impact of delay and congestion. Of the 40 percent that indicated that customers had taken actions to help mitigate the impact of delay and congestion, the following aggregated responses were provided:

- Customers have allowed more driving time for travel through congested areas or to locations with significant congestion
- Customers have changed pickup and delivery hours including:
  - 24-hour access to trailer staging areas/drop yards
  - Early morning/late evening delivery times to help carriers avoid peak hour
  - More efficient loading/unloading processes.

Another area of emphasis commonly cited by respondents is carrier recognition of the impacts of mobility constraints on their customers. As congestion and mobility constraints have increased, the geographical area for just-in-time (JIT) inventory replenishment has decreased. Carriers must be aware of customer efforts to mitigate constraints, as these efforts typically also affect motor carrier operations. Actions taken to minimize effects of constraints on shippers include:

- Incentives for customers to maximize use of trailer capacity by double-stacking pallets during loading
- Incentives for off-hours pickup and delivery appointments (for some segments)
- Carrier efforts to cultivate relationships between drivers and regular customers
- Encouraging customer use of reduced packaging sizes
- Relocating or adding terminals or drop yards closer to customer locations.

A final proposed solution is the development of a more cohesive marketplace between carriers and shippers, where shippers play a larger role in the efficient movement of freight. In this model, motor carriers would provide a driver and a tractor, while shippers would be responsible for maximizing use of trailer capacity.

From the labor unions' perspective, low-cost solutions to address freight mobility constraints would be those that do not increase the operating expense to motor carriers, or jeopardize the safety of truck drivers or the motoring public. The strategies include:

- Empowering motor carriers to more efficiently use union drivers to suit their operational needs, which has improved carriers' ability to work around freight mobility constraints
- Greater emphasis on off-hours schedules for travel in both rural and urban areas
- Lifting tractor trailer route restrictions during off-peak hours, if the road can be safely traveled by large trucks, allowing for greater freight mobility
- Moving more freight at night.

5.4.2 Railroads Improvement Strategies

Strategies often used to respond to rail freight mobility constraints include:

- Contracting out for special skills
- Hiring temporary workers
- Supporting labor training programs
- Establishing labor/management operations planning and troubleshooting teams
- Fast-tracking environmental clearances where possible—including with public-private partnership (PPP) projects
- Rapid installation under traffic (which requires advance planning and logistics support—and may involve temporary re-routing of traffic away from the site)
- Upgrading communication technologies—subject to FCC rules.

The technique of the maintenance/renewal "blitz" began about 10 years ago on lines serving the Powder River Basin coal mines and has become widely used. The technique takes a line completely out of service, say for a long weekend, and then with round-the-clock activity, finishes all steps in the construction process before returning the facility to normal operations. In addition to track renewal, the blitz approach has been used effectively for bridge replacements. The blitz strategy is also a good one for making use of quality off-the-shelf products—which may include pre-spiked track panels (of commercial or company manufacture) distributed along the project site before beginning the blitz. In a somewhat different context, a company- or division-wide safety blitz can quickly focus management and employee attention on a safety shortcoming.

The following low-cost improvements are considered to have high potential of implementation to address rail freight mobility constraints. These are ranked in decreasing order of potential:

- Deployment of advanced technologies
- Train control/advanced dispatching
- Advanced electronic inspection techniques
- On-board sensors
- Rapid on/off maintenance of way machinery
- Trunked digital communications systems
- Electronically controlled pneumatic brakes.

Operational/Technological Strategies: An overriding issue is better communication up, down, and across the organization and to and from customers. A generic response to the survey was that research on IT systems lowering capacity barriers was needed, including outside-the-box thinking, and recognition that the causes of capacity bottlenecks may be different for small and large carriers. Within the rail commodity/operating mix, there seems to be more concern about supporting carload manifest service than unit trains and intermodal operations.

Contributing to this broad concern (and the specific worry about the future of carload business) is the perceived inadequacy of tracking systems. Suggested solutions range from broader use of automatic car identification (ACI) readers and an overhaul of the Car Location Message (CLM) system to comprehensive scheduling of rail operations, including car time at shipper locations. Existing CLM practices are out of date. Technology seen in powered consumer markets must find application in the rail space to ensure improved speed and visibility of shipments, both load and empty, in the entire North American supply chain. There are simply too many errors, passive interchanges, track maintenance delays, etc. to allow fleet optimization and utilization levels to climb aggressively enough to offset the increased cost of shipping goods via rail. As long as this issue is unaddressed, rail will continue to experience slow growth versus its actual utility and value.

It was observed that automatic equipment identification (AEI) readers would not be granular enough for the next generation of computer aided dispatching (CAD), on-board operating and computer control systems, while the level of radio frequency identification (RFID) used for lading may be too granular. Solutions will be found, like global positioning system (GPS) and terrestrial tracking. Capacity modeling will become increasingly important as density increases. PTC technologies, like moving blocks with dynamically calculated safe braking distances and elimination of wayside signals (a major constraint today), are coming. Public policy can help with the issues of standardization and interoperability.

Public Policy/Regulatory Strategies: Respondents had numerous suggestions for public policy changes that would improve freight mobility at low cost to consumers. One respondent noted that

> The elephant in the room is the threat of re-regulation. There is no incentive for rail investors to expand capacity if legislators and the Surface Transportation Board (STB) will limit return [including compensation for risk]. Capping returns at average capital cost at the top of the business cycle virtually prevents investment whose long-term recovery must span the entire business cycle. A shot at earning a premium at the top is needed to carry the investment through bad times. And it is that premium that attracts further capital to expand capacity.

There is the urgent need for national initiatives employing railroads to address energy imperatives and reduction of the nation's carbon footprint. Some respondents suggested investments in passenger transport facilities that could benefit freight operations collaterally. The Investment Tax Credit (ITC) to accelerate investment (a neutral device as among competing companies and management prerogatives) was mentioned as an ideal way to lower mobility costs for users. A stronger Federal preemption to head off local obstructions harming rail mobility projects might be needed. Measures to fund and facilitate PPPs would be much in order.

Despite concerns about "strings" on public funding, many respondents believed that there should be increases in public funding of capital investments in rail infrastructure. A short-line executive stated the need for Federal funding as follows:

> From our standpoint, state assistance programs similar to those in Ohio, Pennsylvania, New York and other states that provide funding for customer-related rail infrastructure would be a major plus. Normally states or local road authorities fund highway improvements associated with new or expanded customer facilities but neither [of the states our short line operates in] provide any funding for customer rail access. Such funding would be particularly helpful to speed the adoption of new technology [-based] safety improvements, which are often difficult to justify for our low-density lines.
>
> Very little research funding finds its way to topics of keen interest to the short line and regional railroad community, yet local railroads now compose roughly 25 percent of the national freight rail network. The relatively modest purchasing budgets of short lines don't encourage suppliers to devote much product development to areas aimed at low density lines. Federal and state government could play a role here to identify cost-effective solutions to improve the safety, efficiency, and utility of the local railroad network.

From the labor unions' perspective, low-cost solutions should:

- Allow special agreements where engineers can transfer, temporarily or permanently, from one seniority district to another to address severe engineer shortages.
- Improve channels of communication so that issues can be worked out at the local level and overlapping management roles are streamlined.
- Continue to allow long-haul crews to meet and swap trains while en route when both crews have sufficient time left to work under the law. Under some circumstances this can be cost neutral and can be implemented in relatively short order.
- Revise the Hours-of-Service limits to allow some flexibility to address worker shortages that develop in a particular region.

5.4.2.1 Methods and Approaches to Selecting Improvements

Most survey respondents indicated that their companies used at least informal cost-benefit analysis in setting capital project priorities. A semi-formal cost-benefit evaluation on every project is utilized where it can be demonstrated that a project can result in capacity or operating improvement. In other cases, where external funding is sought, then a return on investment (ROI) analysis will be undertaken. Financial performance in the form of a rate of return exceeding 15 percent and/or a payback of 18 months or less typically would qualify the project. In general, the required rates of return have to significantly exceed the cost of capital. In the absence of this, the project has to satisfy a regulatory need or else be required to sustain operations.

Most railroads and rail suppliers apparently have a cross-functional senior management team responsible for review of capital investment needs and project priorities. The senior team reviews formal capital requests from managers and directors, and these are supported by standard financial analyses.

5.4.3 Deepwater and Inland Waterways Improvement Strategies

Three major methods of selecting improvement options were identified by the survey respondents:

1. Undertake an evaluation to identify and execute ways to improve or change their business process. Decisions to undertake a change in business process to improve performance are driven by labor rules, capital cost, operation cost, risk, capacity, productivity, and rate of return. This reflects the private-sector approach to decision making that involves constant evaluation for process improvement.
2. Dialogue with key stakeholders to identify problems and ways to address them. Several ports organize meetings among their stakeholders so that labor, motor carriers, regulatory agencies, and others can meet in various committees to address concerns. For example, one "port coordination team" on a major shipping channel meets to determine when to open and close the channel to accommodate vessel traffic requirements. Another terminal operator focuses on its customers to keep them informed of the various factors affecting the delivery process and to work with them on how to improve the system.
3. Discuss Federal regulatory impacts on terminal operations with Federal agencies to address effective operational and enforcement policies so that they can be applied reasonably while meeting the required objective of the initiative.

The following is a priority ranking of actions that are often used to address freight mobility constraints. This ranking reflects the relative effectiveness of the actions. Obviously, regular communication and coordination of activities are the most effective tools in addressing mobility issues.

1. Regularly communicate with elected officials, management, and community stakeholders to garner support for regulatory improvements
2. Coordinate capital improvement planning and improvements with modal and community partners to avoid unanticipated negative congestion consequences
3. Use customized technology programs
4. Support labor training programs
5. Empower problem-solving action groups
6. Prepare and budget for implementing contingency plans.

Among the potential low-cost improvements, the following are considered to have some or high potential of implementation to address freight mobility constraints:

- Reconfigure terminal to add more capacity
- Utilize wireless communications on terminal to facilitate proper storage, ship operations, and gate operations
- Establish regular pre-planning meetings to coordinate ship, rail, labor, and drayage requirements
- Institute on-terminal traffic management by managers
- Deploy "Fast Lane" at gates using paperless checking
- Install auxiliary gate lanes
- Locate secured inspection areas outside of major traffic areas.

These actions are ranked in order from the most likely to the least likely to be used. All respondents indicated that terminal reconfiguration to add more capacity has the highest potential for addressing freight mobility constraints at deepwater ports. This is followed by the use of advanced communication technologies to coordinate and facilitate terminal activities.

Labor unions suggest the following strategies to address freight mobility constraints at the deepwater ports and inland waterways:

- Greater uniformity of trained labor so that individuals can be rotated from one port to another to perform similar jobs at all ports; so a crane operator in Philadelphia, for example, can be moved to operate a crane in South Carolina. The Seafarers union has placed an emphasis on continuous recruiting of labor supply as demand has increased over recent years. Training at the Piney Point School is aiming to achieve its goal of providing well-trained seafarers to take on all types of work required by the industry. They provide all levels of training so that the employers can have well-trained union members who can meet all of the employers' requirements.
- Interoperability and uniformity of systems - currently, each terminal operator has its own individual data systems for clerks, checkers, and longshore personnel to use. If a checker moves from one terminal to another, he or she must be trained in an entirely new system.

Union specialist lock operators and mechanics are frequently on single-person shifts to operate the facilities and must have expertise in the total operational facility as they are the first responders to any difficulties at the facilities. The union representing these workers has worked with management at the local level to counteract contracting out to inexperienced workers.

The Teamsters have responded to mobility constraints by allowing motor carriers more flexible use of Teamster drivers. For example, the Teamsters now allow companies to put empty trailers on rail equipment, whereas before, the contract required motor carriers to use road drivers to do so. Also, to reduce travel during peak congestion times, the union strongly advocates that trucking companies and their customers allow evening and weekend deliveries. In addition, the Teamsters' new contracts create a new type of driver, a "utility" or hybrid driver. This driver offers trucking companies flexibility in working around mobility constraints by allowing the carrier to use a driver in different roles, such as for local pickup and delivery or off-hours pickup and delivery.

5.4.3.1 Approaches in Selecting Improvement Options

The complexity of trying to identify a single process by which to select improvement options restricts system-wide improvement options, especially when so many players are involved who make individual decisions based on their own objectives and business frameworks. Decisions to undertake a business process change focused on performance improvement are driven by labor rules, capital cost, operating cost, risk, capacity, productivity, and rate of return. Three out of the four respondents indicated that they routinely employ a cost-benefit analysis in evaluating and selecting alternative improvements. The survey respondents listed several factors considered in evaluating improvement options, including:

- Safety
- Labor rules
- Capital cost
- Operating cost
- Risk
- Productivity
- Rate of return

- Clearly beneficial results
- Regulatory compliance (including Customs and Border Protection enforcement process improvements that benefit the shipping line or the terminal)
- Minimizing financial impact to stakeholders.

5.5 Summary of Improvements

Table 26 presents the range of options for different types of constraints for highway movements. This table is based on information on completed low-cost improvement projects by various stakeholders. While most constraints for the highway mode are physical, the improvements are a combination of physical and operational actions. It is acknowledged that regulatory actions are more complex and not easily or quickly implemented. This is because regulatory changes would involve extensive rulemaking effort. Information on highway projects were obtained from projects implemented in Florida, Maryland, Minnesota, New Jersey, Ohio, Texas, Utah, and Washington.

Table 27 summarizes actions commonly taken by motor carriers to avoid or eliminate the effects of constraints on their operations. These actions are intended to guide private-sector

Table 26. Highways—public-sector improvements.

Physical Constraint	Improvement Options
Turning Radii	Add turning lane
	Widen lane
	Extend existing lane
	Modify median bull noses
Weaving	Add lane
	Add auxiliary lane
	Extend turning lane
	Add turning lane
	Extend existing lane
	Redirection of traffic
	Restriping
Lane Drop	Add auxiliary lane
	Extend ramp length
Inadequate Interchange Capacity	Add auxiliary lane
	Add turning lane
	Add lane
	Add traffic signal
	Extend acceleration and deceleration lanes
	Extend ramp length
	Ramp metering
	Interchange realignment
	Widen lane
	Speed reduction
	Add warning signs
	Improve road signage
	Channelization
	Restriping
Narrow Tunnel	Add a lane
Steep Grade	Add a passing lane
Inadequate Parking	Provide parking facilities even with no facilities[a]
	Pave shoulders
	Widen shoulders on mainline and ramps

Physical Constraint	Improvement Options
Inadequate Mainline Capacity	Add a lane
	Add warning signs
	Speed reduction
	Add channelization
	Improve road signage
	Restriping
	Signal upgrade
	Revise merging/diverting area
Inadequate Intersection capacity	Add dedicated turning lane
	Add a lane
	Extend turning lane
	Auxiliary lane
	Widen turning lane
	Signal phasing
	Intersection layout improvement
	Proper roundabout design near freight facilities
Operational Constraint	**Improvement Options**
Traffic Control (lack of, or poor signal timing)	Signal installation
	Traffic signal upgrade
	Synchronize signal phasing
	Signal phasing
Poor Signage/Warning Signs	Improve road signage at interchange entrances and exits
	Better advance navigational signing
Steep Grade with Ramp Meter	Remove ramp meter
	Relocate ramp meter
	Alter ramp metering operation
Shortage of Truck Drivers	More flexible use of drivers
Regulatory Constraint	**Improvement Options**
Truck Lane Restrictions	Modify restrictions
Parking Restrictions	Revise parking restrictions
	Provide additional parking
	Allow parking on paved shoulders and ramps[b]

[a] - likely opposition by truck stop interest competitors
[b] - risk of crashes and security

Table 27. Highways—private-sector actions.

Constraint Type	Potential Action
Physical and Operational	• Use of alternate routes • Reschedule trip/delivery • Deploy in-cab communication • Add equipment/drivers/ resources • Hire drivers • Higher pay for drivers operating in congested areas • Operate less-than-full-load trucks • Incentives for off-peak period operations • Facilitate data exchange between shippers and motor carriers • Incentives to customers to maximize use of trailer capacity
Regulatory	• Seek regulatory changes • Report inefficiencies to government agencies

decision makers in selecting proven strategies to overcome the effects of mobility constraints while achieving acceptable productivity levels.

For rail and water modes, operational constraints are more prominent than physical and regulatory constraints. For rail, data were derived from implemented projects in Alaska, Arizona, Illinois, North Carolina, Missouri, and Washington. Tables 28 and 29 summarize the constraints and corresponding improvement options for the rail and water modes, respectively.

The constraints and corresponding improvement options presented in these tables together with the detailed implemented project information contained in the database are integral components of the methodology described in the next chapter. Also these options are described in greater detail in the catalog of improvements later in this report.

Table 28. Railroads—improvements.

Physical Constraint	Improvement Options
Inadequate Track Capacity	New track (siding) turnout
	Curve superelevation
	Realign tracks
	Upgrade siding track
	Extended siding track
	Provide crossover
	Connection tracks
	Centralized traffic control system
	Branch line upgrades
	Tie replacement
	Track surfacing
	Advanced electronic inspection techniques
	Improve crossing warning systems and make current passive crossings active
Inadequate Capacity of Yards and Port Terminals	Expansion of carload terminals
	Internal gateway facilities
	Expansion of intermodal terminals

Physical Constraint	Improvement Options
Inadequate Siding Capacity	Extended siding track
	New siding track
	Turnout
	Realign tracks
	Centralized traffic control system
	Connection tracks
Operational Constraint	**Improvement Options**
Lack of Skilled Labor	Hire temporary workers
Inefficient Labor Utilization	Negotiate contracts to accommodate "limbo time"
Switching Conflicts/ Inefficient Switching	Remote switching
	Upgrade/reconfigure interlocking, low-emission switch engines
	Coordinate operations of Class I and short-line/regional railroads
Outdated Communication and Signaling	Centralized traffic control system
	Signal improvements – advanced technologies
	On-board and wayside defect detection and other advanced sensors
	Trunked digital communications systems

Table 29. Deepwater ports and inland waterways—improvements.

Operational Constraints	Improvement Options
Lack of Crews	Hire temporary labor
	Support labor union and training programs
Inefficiencies in Operations of Terminal Yard/Gates – causing congestion and delays	Expanded gate hours
	Congestion pricing
	Trucking appointment system
	Automated yard marshalling and inventory control
	Joint inspection facilities
	Establish flexible labor shifts
	Partnership to accommodate uneven demand cycles
	Utilize wireless communications to facilitate proper storage, ship operations, gate operations
	Incentive-based program to shift freight from trucks to rail
	High-speed gates/fast lane using paperless checking
	Multi-pick cranes
Terminal Yard/Gates – Roadway Connector Capacity	Synchronizing traffic lights
	Traffic management
Rail Intermodal Connector Capacity	Fast rail shuttles
	Integrated maritime and rail movements
	Off-dock container yards
	Partnership to reduce passenger/freight rail use conflicts

Regulatory Constraints	Improvement Options
Supply Chain Connectors	Smooth out mismatched labor structures
Labor Laws and Restrictive Contractual Limitations	Negotiate training terms and conditions to increase skills and trained labor supply
Inefficient Labor Utilization	Negotiate contract to accommodate "limbo time"
TWIC requirements and lack of card-reading equipment	Upgrade card readers
	Use existing software packages for card readers
Physical Constraints	**Improvement Options**
Rail Intermodal Connector Capacity	Expanded rail connections
Terminal Yard/Gates – Roadway Connector	Widen local roads
	Restriping to add lanes
	Auxiliary gate lanes
Inadequate Capacity of Terminal Yard/Gates	Locate secured inspection areas outside major traffic areas
	Terminal reconfiguration to add capacity

CHAPTER 6

Methodology for Identifying and Evaluating Improvements

6.1 Introduction

A major output of this research is a computer-based methodology that decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and regulatory or public policy actions designed to enhance freight mobility by addressing identified constraints. Having defined and characterized freight mobility constraints and developed the criteria for low-cost and quickly implementable improvements, this chapter describes the framework of the methodology. The framework acknowledges that a proper methodology would be integrated into the standard Project Development Process, which each state DOT and MPO is required to have if they were to use state or Federal funds to implement such projects. The framework further acknowledges that:

- Most candidate projects are developed from an approved state or MPO planning process.
- The planning process includes some kind of freight stakeholder input process by which candidate projects are suggested.
- Some kind of preliminary on-the-ground analysis has been conducted to ensure that the project can be implemented within the resources available and without more significant environmental complexities.

The following sections describe the methodology followed by a discussion of how it could be integrated into the planning process.

6.2 Framework of Methodology

The purpose of the methodology is to assist public- and private-sector decision makers in identifying and evaluating low-cost capital, operational, regulatory, or public policy actions to improve freight mobility. Conceptually, the methodology is designed to be a simple application tool where decision makers make selections to define the constraint and receive feedback on possible actions to address it. The user then selects possible improvements that can address the specific constraint under consideration and also proceed to view examples where the actions had been implemented or proposed. The selections are designed as simple dropdown boxes that include options. The methodology is backed by a database of historical low-cost improvement projects. The value of the examples is intended to illustrate the applicability of improvements and to guide users in making suitable selections. The methodology is designed to be data driven where the database of implemented improvements can be updated and expanded as new project information becomes available. The overall framework of the methodology is depicted in Figure 22 and a concept of operations is described below.

The framework has three main components: (i) characterization of constraint by identifying its mode, location, and type; (ii) identification of improvement options; and (iii) evaluation of improvement options.

6.2.1 Characterization of Constraint

The first step in the proposed methodology is for a user to select the freight transportation mode of interest, e.g., highway, rail, or deepwater port and inland waterways.

For the selected mode, the user next has the choice to identify a subcategory of the selected mode and elements of that subcategory. For example, the subcategories of the highway mode include major functional classes (rural and urban). The user can further identify the location within the subcategory where the constraint occurs, e.g., mainline, interchange ramp, intersections, construction zone, weigh stations.

Similarly for rail, the subcategories are Class I, regional, and short-line rail and the constraint location would be

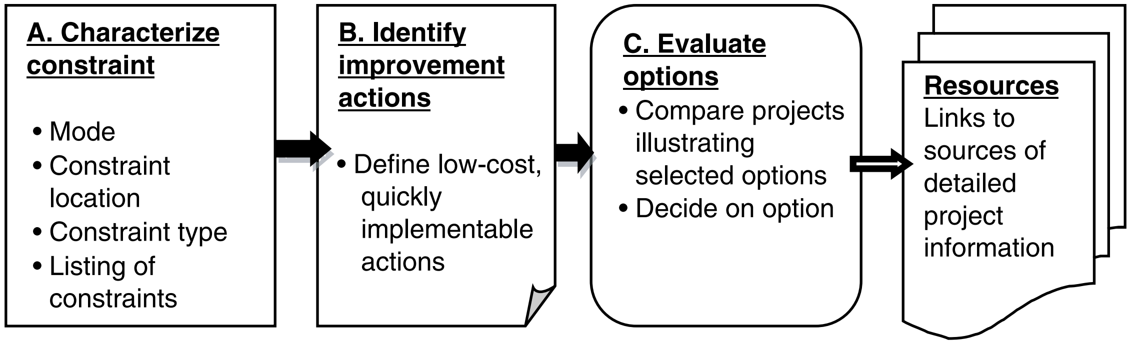


Figure 22. Framework of methodology.

mainline, siding, terminal/yard, or IT/process improvement. For deepwater ports and inland waterways, the subcategories are deepwater ports and inland waterways, and the constraint locations are "on the terminal," "outside the gate," or "waterside" to designate physical zones of operation that require various partners and financial responsibility to implement actions that address constraints.

The next step is to classify the constraint under consideration into one of the three types (i.e., physical, operational, or regulatory). Definitions of the different types of constraints are displayed to guide the user in selecting the appropriate type of constraint. Figure 23 illustrates one example of applying the above steps.

For the selected type of constraint, a list of constraints that could occur at the constraint location selected are displayed; from this list, the user can select the constraint that best fits the situation under consideration. Standard descriptions for the selected constraint are then displayed as pop-up boxes to confirm that the selection fits the situation under consideration. This step is shown in Figure 24 and illustrated with examples of physical constraints for the highway mode. Similar lists for the other constraint types and for each mode are included in the database.

6.2.2 Selection of Improvements

This second component of the methodology guides the user to identify the potential low-cost improvement options to address the constraint identified in the previous component. The first screen in this component of the framework displays the definition of a low-cost, quickly implementable improvement specific to the selected mode.

Once the constraint has been characterized, the user can then make a selection from a list of possible options that can be used to address that constraint. The improvement options displayed are determined by the type of constraint. The list of improvement options are developed from the results of the literature review, interviews, and survey of public- and private-sector stakeholders.

After selecting the improvement, the user can view examples of projects implemented without going through the evaluation process (see Figure 22). The user can also select multiple improvements and choose to compare the selected options based on their characteristics or view examples of each option. Note that the examples of improvements in the database pertain to the public-sector actions only. Even though improvements are determined by the type of constraint, it is possible

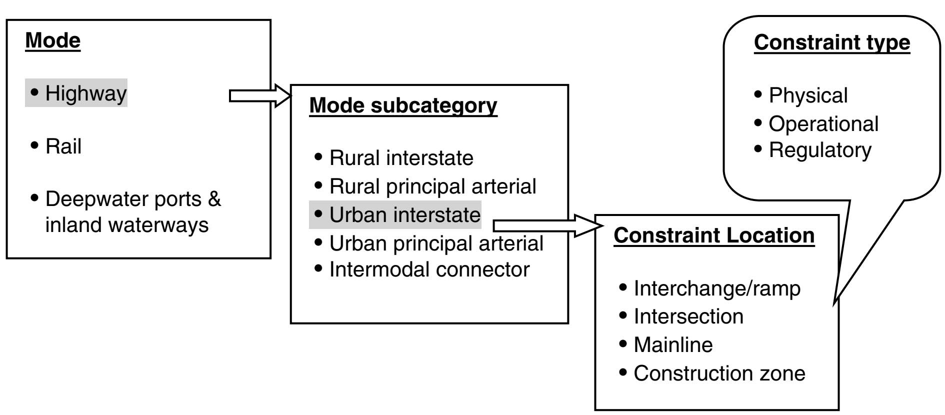


Figure 23. Characterization of constraint.

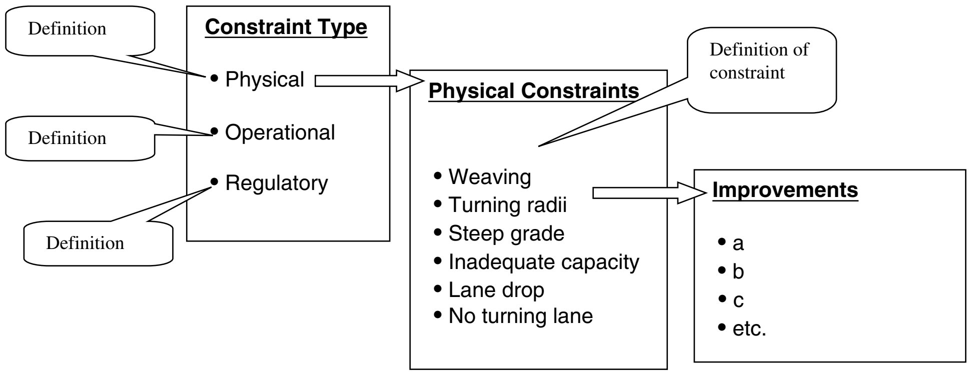


Figure 24. Selection of constraint.

that some constraints may be addressed by different types of improvements. For example, the public sector might implement a regulatory action to address an operational constraint. For this reason, the improvements are not grouped by type. Instead, for each selected constraint, improvements that have been successfully implemented elsewhere are displayed. Figure 25 illustrates this step and shows the relationship between the first two components of the framework.

It is important to distinguish between public-sector improvements and private-sector reactions to minimize the effects of the constraints. For the highway mode, public-sector improvement options are actions that are designed to remove or minimize the effects of the constraint. The private-sector options, on the other hand, are reactions to minimize or avoid the effects of the constraints, but do not remove the constraint. For the rail mode, since ownership of the railroads is private, public-sector improvements are limited except for regulatory actions. Furthermore, based on information gathered, the constraints are more operational or regulatory and less physical in nature.

Freight mobility constraints associated with deepwater ports and inland waterway modes are influenced to some extent, but not exclusively, by the highway and rail intermodal links to the ports. Consequently, some of the physical constraints are influenced by these intermodal connectors. Others, however, are totally within the jurisdiction of private- or public-sector

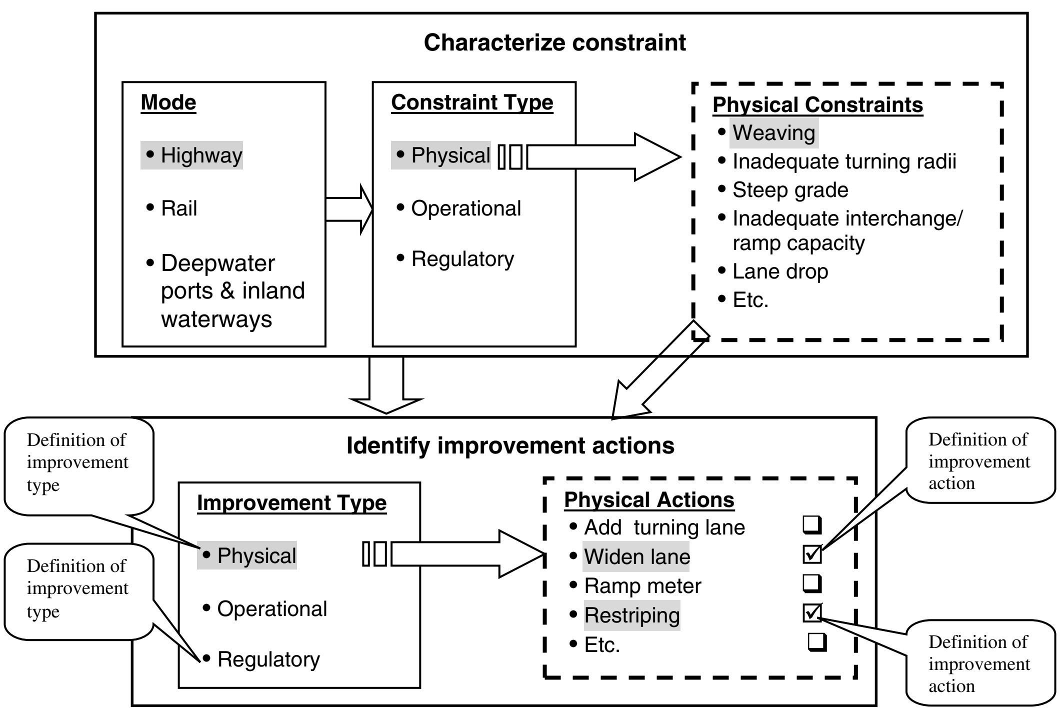


Figure 25. Low-cost improvements based on constraints.

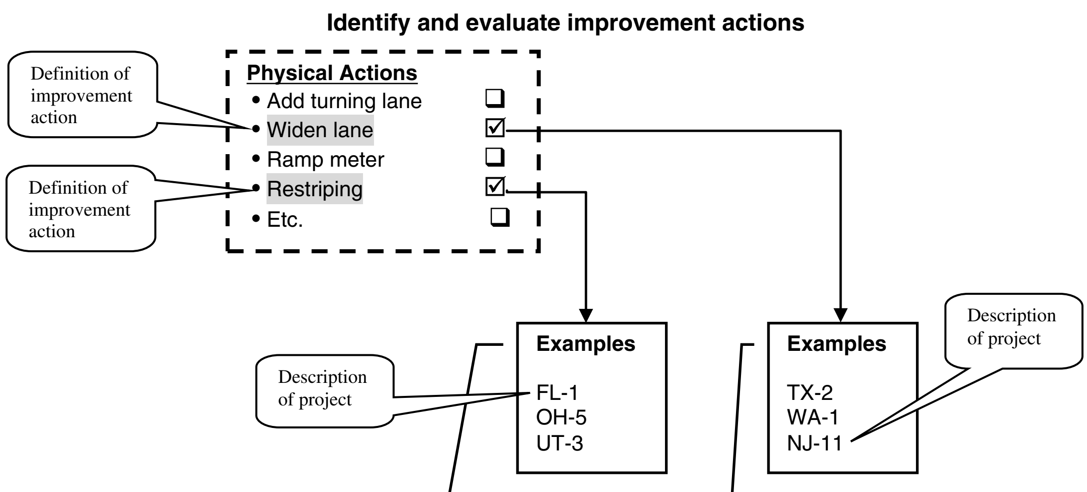
terminal operators and occur within the boundaries under their control. Due to the competitive nature of freight-system operators and modes, it is the challenge of the freight transportation system to encourage the individual operations within the entire freight mobility transportation system to work together to coordinate their individual improvements. This works across all modes regardless of where their physical operations are located.

6.2.3 Evaluation of Improvement Options

This component of the framework enables the user to view details and compare implemented (or proposed) examples of the option(s) selected. For the selected options, a reference list of projects in the database where the options have either been implemented or are under consideration are displayed. The user can select from the list of projects and view details to compare and evaluate the options. The details include descriptions of the projects; location, date, and duration of implementation; before and after values of performance measures; cost; and lessons learned. The projects are identified by project numbers that include the state's name abbreviation to facilitate a decision on which examples to view in detail. Where multiple options are selected, the characteristics of these multiple options are displayed so that the user can compare different improvement options as illustrated in Figure 26. This process combines qualitative and quantitative factors.

The user has the option to go back to the improvement selection page to select different alternatives. Similarly, the user can select different projects to view and/or compare.

The tool also provides links to sources of detailed project information that users can access. These sources are project reports, documents describing the improvements, or websites where further related information can be found on the



Characteristic	Option 1	Option 2
Project name		
Mode		
Location of constraint		
Constraint		
Improvement		
Description of project		
Location of project		
Date of implementation		
Performance measure		
Pre-improvement value		
Post-improvement value		
Cost		
Benefits		
Selection criteria		
Implementation duration		
Lessons learned		

Figure 26. Comparison of improvement options.

implemented projects. For the project reports, the contact information of the publishers are also provided.

6.2.4 Query Database

The framework is structured such that the user can directly query the database of implemented projects based on user-defined criteria without having to go through the constraint characterization and improvement selection process. The search criteria are constraint, improvement, or project name. In the query mode, once the user selects the search criterion, the list of projects satisfying that criterion is displayed. The user can then select a project for detailed review or the user can select multiple projects for comparison. The framework allows the user to start a new search or go through the wizard mode to evaluate the constraint and identify appropriate improvements.

6.3 Software Application

The methodology described above is encapsulated in a software application tool. The prototype of this tool was developed as a standalone product using Microsoft® Windows applications based on the .Net Framework 2.0 programming platform. This application has a wizard-like interface that guides users in making appropriate choices or selections.

6.4 Feedback and Continuous Update of Database

To enhance the usefulness of the tool, it is desirable to include a mechanism to keep updating and adding new options to the database as additional information becomes available. There are two possible methods for doing this: (i) analysts could actively seek additional data for the database, or (ii) practitioners could have the option of sending success stories to a database manager, and the data would then be included as part of the tool. Regardless of the source of new data, extensive effort will be required to fully populate the database with good examples. Since no standard process exists to define, describe, or measure such freight mobility constraint alleviation projects, the process of collecting a substantial number of candidate examples will continue to be time consuming and expensive. The methodology as described in this project would be the beginning of a long, multi-year, multi-state, and multi-urbanized area effort to collect sample projects to populate and update the database. The database and methodology would need to become part of a collaborative effort by many jurisdictions to provide the data for the future analyses.

Once such a collaborative data collection mechanism is established, it will be necessary to convert the tool to a web-based application that will include a feedback screen to capture strategies selected by policy/decision makers to resolve mobility issues. This information will contribute to the database and add to the intelligence of the application. For example, as options and strategies are selected, the program will apply a factor to reflect its level of usage. This will allow other users to see the history of the options selected as they make decisions. Also, the tool will include a feature that allows users to provide feedback on the level of success or failure of the strategy they selected. This information can be used to enhance the value of the strategy to mitigate similar problems.

6.5 Integration into Planning Process

As noted in the introduction, the methodology described above is intended to integrate into the transportation planning process and the project development process. Each state DOT and each MPO is required to conduct a systematic and ongoing planning process, which, among other things, identifies transportation bottlenecks. Since the 1991 enactment of the Intermodal Surface Transportation Efficiency Act, freight issues are required to be included in the planning process. These planning requirements have resulted in a variety of freight-planning activities at state DOTs and MPOs including:

- Improved collection of freight data incorporating:
  - Freight origin and destination data
  - Freight volumes across the network and at selected links and nodes of the network
  - Forecasts of freight growth rates to enable prediction of future levels of congestion
  - Creation in some cases of freight models, which generate freight demand predictions across the network or at specific links
  - Feedback through studies and surveys of businesses and industry to understand the impacts of freight systems on the operations of all modes (rail, road, sea, barge, or air)
  - Improved estimates of costs such as the value of time for shipments, the values of cargoes moved, and the estimated contribution of freight efficiency to overall economic competitiveness
- Identification of freight stakeholders including:
  - The formation of freight stakeholder councils
  - Identification of major freight producers and consumers among local businesses and industries
  - Solicitation of input from modal operators about their unique issues such as the needs of motor carriers, railroads, port operators, and other transport sectors
- Identification of freight bottlenecks including:
  - Correlating high truck volumes on freeways to known points of freeway congestion
  - Identification of intersections that serve high truck volumes

– Identification of economic impacts to shipping, freight, and trucking businesses due to winter weather road closures
– Identification of physical roadway constraints into key freight nodes such as ports, manufacturing areas, intermodal yards, airports, or other areas of freight generation or transfer
– Identification of rail constraints such as track slow orders indicating maintenance problems, low overhead clearances that restrict "double stacked" container train movements, at-grade crossings, narrow bridges restricting track or siding expansion; load-limited rail bridge structures, and outdated and poorly located railroad yards and intermodal facilities.

Planning traditionally occurs at two levels, the planning level and the project level. The planning level generally is a "macro-level" process that examines planning issues across an entire network, whether the network is an entire state, a metropolitan area, or a smaller area within the state or metropolitan area. Planning level analysis tends to be focused upon broad, more generalized issues such as:

- Collaborative development of transportation policies
- Establishment of public input and collaboration processes
- Forecasted rates of growth in transportation volumes in all modes
- Identification and prioritization of areas of congestion
- Measurement of the effects of potential projects upon that congestion
- Evaluation of transportation's effect upon air quality
- Integration of potential projects into the land use plans and policies of communities
- Identification of specific projects to be pursued.

6.5.1 Transportation Planning Process

Figure 27 illustrates how the planning process begins with broad regional goals and progresses methodically down to the identification of individual projects and strategies for operating the system. The low-cost freight bottleneck evaluation methodology is intended to assist the larger planning process in the areas of developing the Transportation Plan, making trade-offs, identifying projects within the plan, and identifying operational strategies.

The Transportation Plan development process identifies a variety of transportation policies, strategies, long-term needs, and generalized descriptions of projects that will address those needs. It usually includes the development of alternative scenarios. Different scenarios can be based upon alternative assumptions about growth rates or funding levels for the region. The low-cost freight constraint evaluation methodology can be used to identify the most likely types of improvements that could be considered to address freight mobility constraints, once the constraints have been identified through the transportation modeling process. Usually, MPOs utilize transportation planning models that are sophisticated enough to identify areas of congestion. Those known areas can be reviewed through the methodology to identify likely potential solutions, which can be included in the long-term Transportation Plan.

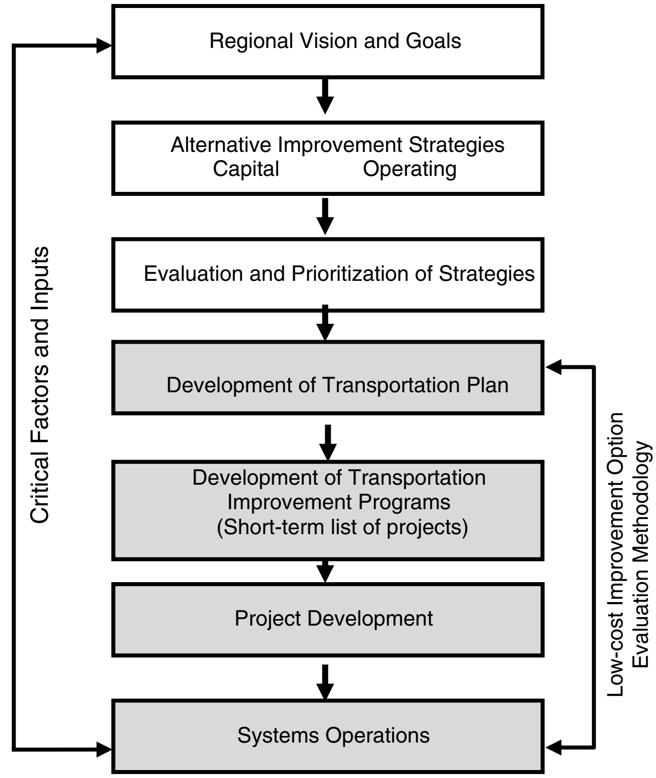


Figure 27. Integration of methodology into transportation planning process.

The ultimate product of planning is the identification of projects, strategies, and processes for addressing transportation needs. These projects and strategies are identified in greater detail after the Transportation Plan stage in the Transportation Improvement Program (TIP). The TIP is a metropolitan area's collection of projects or strategies to be deployed, generally for the next 4- or 5-year period. The TIPs are specific collections of projects that can be funded with available state, local, and Federal funds, which have been evaluated for air-quality impacts, and which have been approved by their communities following a public-involvement process. The Transportation Plan generally has a 20-year horizon, which would include four to five TIPs.

The methodology can be applied at the TIP level as well as at the Transportation Plan level. Generally, the Transportation Plan development process produces a list of congestion chokepoints and promising freight strategies, which must be further prioritized into chronological periods. The potential freight bottleneck projects identified through the Transportation Plan can be further evaluated and prioritized through the methodology for prioritization in the short-term TIP. Those projects that appear to have the greatest benefit in terms of freight volumes, sensitivity to the improvement strategy, or support by freight stakeholders can be adopted for the TIP.

Many MPOs and state DOTs have developed Freight Advisory Councils. These tend to be collections of freight-system users and consumers, such as trucking firms, port operators, local shippers, local businesses, railroad operators, and waterborne freight operators in regions that have marine ports or inland waterways. These councils typically advise the MPO or DOT at both the plan development stage and the TIP development stage. The methodology would be an appropriate tool for the Freight Advisory Council members to use to help evaluate the potential scope of projects at congested locations.

6.5.2 Project Development Process

All projects constructed using Federal transportation funds must be derived from an approved Transportation Plan and TIP. However, those "planning level" approvals are not sufficient to lead to the actual construction of a project or deployment of a strategy. An additional "project-level" evaluation process also is required, which includes analysis of engineering, environmental, social, and financial alternatives. This analysis begins with evaluation as to the needed number of lanes; proper horizontal and vertical curvature; sight distances; length of merging or weaving areas; and the type, size, and location of any structures. As those engineering details are refined, the project's more precise scope, cost, footprint, and impacts are evaluated against their effect upon the environment, the neighborhood, their effect upon the cost of the project, and the project's overall acceptability to the surrounding community. Many such details are not known at the earlier planning level.

The methodology lends itself to incorporation into the project development process (Figure 28). Once a site has been identified for improvement in the TIP, a multidisciplinary team could field-review the location for consideration of its feasibility. Any obvious constraints to the project could be taken into consideration and used to determine if the most highly recommended bottleneck strategy appears possible after this initial, cursory investigation. Such initial screening also may be possible by relying on geographic information systems and other inventories if they exist. Reviews of aerial photographs, reviews of utility plans, right-of-way maps, and other information sources could provide insight into the feasibility of a proposed solution.

The engineering details as to precise length of turning lanes, exact radii, elevation of structures, location of drainage facilities, and other details will then clarify the impacts upon adjacent property and utilities. If these more exact details then reveal impacts upon property or utilities that invalidate project costs or feasibility assumptions, then the rank-order list of strategies for that location can be revisited. If the leading option is not possible, the second most promising strategy from the methodology could be pursued. For instance, at an intersection if a turn lane or radius improvement is not possible, then signal timing improvements could be the next-best option. Likewise, the element of time could be applied to the solution. If the turning lane or turning radius solution has to be deferred until it can be afforded, the signal-timing solution could be implemented in the short term.

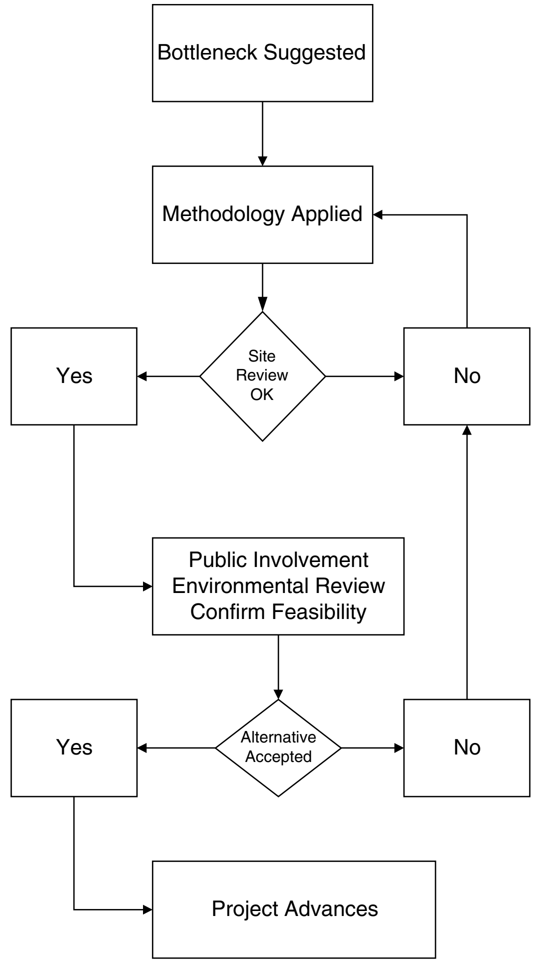


Figure 28. Integration into project-development process.

In these various ways, the methodology can be incorporated into the long-range planning process, the shorter-term TIP development process, or the specific project development process.

The goal is to encapsulate the methodology in a stand-alone software application that can be used at different stages of the transportation planning and project development process as described above, as well by private-sector decision makers.

6.6 Evaluation of Beta Version of Tool

The initial version of the prototype tool was subjected to beta testing by representatives of all modal stakeholders. Samples of beta testers were drawn from stakeholder representatives who were interviewed and/or responded to the survey as part of the data collection tasks under this project. Even though the beta testers were randomly selected, the sample is not considered to be statistically representative of the populations of the various segments of stakeholders. The objective of the beta test was to obtain feedback from potential users on the usefulness, user friendliness, and weaknesses of the tool and on aspects that needed improvement. The software tool, user guide, and evaluation form were delivered to potential beta testers by email. Beta testers were asked to install and run the software tool and provide feedback using the evaluation form. To avoid any biases, beta testers were not given any specific guidance regarding the types of scenarios to run. A blank evaluation form is included in Appendix E of this report. The recommendations from the beta testing effort were implemented in revising the tool.

The results of the beta testing indicated that the tool is easy to use with or without a user guide, and easy to navigate. The program is perceived to be easy, direct, and the sequence logical. It was also noted that the interface is clear and easy to understand. The *User Guide* for the tool is also noted to be clear, easy to follow, and straight to the point. However, installing the program from the email attachments or from CD is generally not very easy. This is not because of the program per se but because of firewalls and PC security restrictions within the organizations.

The general consensus was that the tool provides a structured handy format and configuration for accessing information on proven low-cost improvements to address freight mobility constraints. As standalone software, information contained in the database is static and cannot be easily updated. A web-based approach with the functionality for updates to the information is recommended to not only facilitate updates and render the database dynamic but also to overcome installation problems due to the cyber security firewalls implemented by the IT departments of some agencies that prohibit installation of unauthorized software. Above all, a web-based approach is believed to enhance the utility and usefulness of the tool.

CHAPTER 7

Catalog of Improvements

7.1 Introduction

The primary focus of this research project has been to develop a method (or tool) that public- and private-sector decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and public policy actions that can enhance freight mobility by addressing persistent system constraints. The tool is applied to develop a catalog of low-cost actions or classes of actions that can be quickly implemented to address the nation's freight-system mobility constraints, especially along corridors or at locations that impact freight mobility at a national level.

The approach in developing the catalog of strategies recognizes the inherent conflict or disconnect between the criteria of quickly implementable low-cost improvements and large capital investments required to expand the capacity of the freight transportation system, especially for projects of national significance. In other words, addressing freight mobility constraints at locations that may impact freight mobility at national levels would require large capital investments that encompass low-cost physical improvements. Low-cost improvements are effective in eliminating and/or reducing the congestion at these locations. With this recognition, the theme in developing the catalog of actions is to identify proven low-cost improvements that have the potential to enhance freight mobility to noticeable extents even though such actions may not by themselves necessarily remove the constraint entirely.

Depending on the mode of freight transportation, the low-cost improvements could be more operations, regulatory, policy, or technology oriented and less physical. While low-cost improvements for the highway mode may include all types of actions (i.e., physical, operational, and regulatory), those for rail and ports may not include physical actions. For physical low-cost improvements, site and traffic characteristics and other factors contributing to a constraint at a given location may not necessarily be identical to other locations. Therefore, improvement strategies presented in the catalog are generic; however, implementation at a particular location would require consideration of specific site characteristics and operational practices. Similarly, given the uniqueness of each deepwater port, an effective action at one port may not necessarily be effective at another port.

7.2 Approach to Developing Catalog of Strategies

In discussing options to address the capacity issues on the freight transportation system, greater understanding is needed of what drives private- and public-sector decision makers to want change, to be willing to pay for it, and to work together to maximize the return on investment in terms of meeting their goals, both quantitative and qualitative. Given the disparities of how each sector defines and measures success, it is important to consider shared, cooperative project implementation to reconcile any conflicts between these values (i.e., public versus private, national versus local, and high-cost versus low-cost improvements), focusing on projects that use relatively low-cost operational strategies or technology innovations to address capacity and mobility constraints.

Recognizing that the characteristics of each mode in terms of the level of public- and private-sector involvement and partnership in decisions regarding funding improvement projects determine the approaches to addressing freight mobility, different approaches are used in developing the catalog of strategies. The catalog of improvements are developed from case studies that represent projects that have been implemented in different parts of the country and to address a variety of freight mobility constraints. The improvements target locations or corridors where major constraints within each modal freight transportation network occur. Addressing these constraints is expected to improve freight mobility significantly at a national level. The following subsections discuss the locations of major freight mobility constraints and present a catalog of low-cost improvements to address specific constraints for each mode.

7.2.1 Highways

Locations of nationally recognized bottlenecks in the highway freight transportation system present opportunities for implementing low-cost improvements to help alleviate the constraints. The freight bottlenecks study (*12*) identified the top 30 freight highway bottlenecks to be poorly functioning interchanges on the NHS. These bottlenecks were identified based on analysis of the performance in terms of volume/capacity ratios and delay derived from freight flow data. The study has shown that more than 70 percent of bottlenecks occur on the interstate highway system and 42 percent were interchange related. These top 30 bottlenecks occur at urban interchanges in metropolitan areas with high population densities and major freight activity centers. The study also concluded that low-cost improvements can result in significant improvements in traffic flow. Analysis of freight performance measurement data (*88*) re-ordered the top 30 freight bottlenecks. This latter analysis was based on truck traffic volume and reductions in truck speed below the posted speed limits through these interchanges. Table 30 shows the locations of the top 30 bottlenecks and their traffic and other performance

Table 30. Performance characteristics of top 30 highway bottlenecks (*58, 88, 89*).

CSI ranking (2002)	ATRI ranking (2009)	Location	State	Freight Congestion value	AADT (2007)	V/C (2002)	AADT (2002)	Truck % (2002)
5	1	I-80 @ I-94 Interchange	IL	2,722,629	144,602	1.104	128,049	24.0%
19	2	I-95 @ SR-4 Interchange	DE	1,435,661	93,979	0.923	88,425	15.5%
9	3	I-90 @ I-94 Interchange	IL	921,688	175,548	1.151	163,805	6.0%
3	4	I-285 @ I-85 Interchange ("Spaghetti Junction")	GA	899,899	286,300	1.850	254,600	16.0%
13	5	I-95 @SR-9A (Western Hwy)	NY	656,190	98,834	1.187	79,755	5.0%
10	6	I-40 @ I-65 Interchange (east)	TN	446,933	192,073	1.925	114,280	17.1%
6	7	SR-60 @ SR-57 Interchange	CA	426,569	344,294	1.173	216,000	12.0%
24	8	I-10 @ I-15 Interchange	CA	382,200	289,504	1.190	258,000	12.0%
21	9	I-45 @ US 59 Interchange	TX	318,853	265,768	2.065	212,241	7.0%
26	10	I-45 @ I-610 Interchange	TX	259,704	301,828	2.396	260,770	8.1%
4	11	I-20 @ I-75/I-85 Interchange	GA	234,258	452,556	1.500	199,000	16.1%
2	12	I-17 (Black Canyon Fwy): I-10 Interchange (the Stack)	AZ	225,892	309,032	0.985	255,371	9.1%
25	13	I-95/I-495	MD	183,772	260,904	1.912	185,125	7.1%
1	14	I-710 @I-105 Interchange	CA	156,987	280,731	1.393	224,000	9.0%
14	15	I-71 @ I-70 Interchange	OH	144,772	188,724	1.648	107,722	17.0%
7	16	I-80 @ I-580/I-880 in Oakland	CA	144,009	292,437	2.241	177,763	9.0%
12	17	I-75 @ I-85 Interchange	GA	138,824	353,005	1.018	295,000	16.0%
15	18	I-880 @ I-238	CA	129,421	339,634	1.206	271,000	10.8%
18	19	I-695/I-70 and I-95 exit 11	MD	119,629	217,885	1.983	165,050	7.0%
20	20	I-10 @ I-110/US 54 Interchange	TX	115,516	232,273	1.379	200,677	7.8%
30	21	I-25 @ I-76 Interchange	CO	107,116	246,429	1.198	237,839	9.0%
27	22	I-10 @ I-410 Loop North Interchange	TX	93,066	193,670	1.747	117,179	7.8%
17	23	I-285 @ I-75 Interchange	GA	58,784	211,107	2.108	153,600	16.1%
11	24	I-290 @ I-355 Interchange	IL	56,591	239,337	1.782	213,906	9.0%
23	25	I-10 @ SR-51/SR-202 Interchange (Mini-Stack)	AZ	51,486	339,804	1.955	152,880	7.0%
28	26	I-110 @ I-105 Interchange	CA	40,647	365,953	1.484	230,000	6.0%
16	27	SR-91 @ SR-55 Interchange	CA	36,746	315,719	1.103	298,000	8.1%
29	28	I-95 @ SR-595 Interchange	FL	28,291	315,890	1.395	288,000	9.0%
8	29	I-405 (San Diego Fwy) @ I-605 Interchange	CA	16,732	472,480	1.376	377,000	6.0%
22	30	SR-134 @ SR-2 Interchange	CA	3,200	235,433	1.083	205,000	6.2%

Note: Freight Congestion value = number of trucks multiplied by difference between average and speed limits characteristics (also shown in Figure 3). The traffic data and congestion measures (indicated by volume/capacity ratios) for these locations were derived from FAF^2 traffic analysis data (*58*). The values shown in Table 30 represent maximum v/c ratios and corresponding AADT and percentage of trucks in the fleet for the critical leg of each interchange. Table 30 also shows the AADT for 2007 derived from the FAF provisional estimates.

The challenge in developing a catalog of low-cost physical improvements is the lack of specific site (geometric) data at these locations. However, as noted previously, the functional highway classes (i.e., urban interstates) where these top 30 bottlenecks and the locations (i.e., interchanges or ramps) where the constraints typically occur are known. Based on the knowledge of the location of the constraints, the methodology was applied to identify the range of constraints and then identify the applicable low-cost improvements for each constraint.

Table 31 presents the catalog of improvements to address freight mobility constraints encountered on the highway system. For each constraint, a single improvement or a combination of improvements can be implemented depending on the severity of the constraint or the physical conditions on site or both. Note that these improvements are generic in the sense that they are not designed to any specific site condition or location. This catalog is intended to serve as a guide and does not include any design details or specifications for implementation.

7.2.2 Railroads

Within the context of improving freight movement by rail, the most urgent policy need does not appear to be investing in expensive projects like double-tracking mainline rail freight corridors, expediting port access, and building new port terminal capacity, but rather smart investments to address persistent operational and site-specific weaknesses in the freight transportation network. In developing a catalog of low-cost improvements, the first step is to identify locations or corridors within the rail freight transportation system where major bottlenecks occur whereby alleviating congestion at these locations would improve rail freight movement at the national levels. For example, in 2007, the Alameda Corridor East and

Table 31. Catalog of low-cost improvements for highway system constraints.

	Constraint	Constraint Description	Improvements
Physical Constraints	Weaving	Where traffic must merge across one or more lanes to access entry or exit ramps. Occurs at closely spaced interchanges/ short acceleration lanes	• Add auxiliary lane to connect an on-ramp and off-ramp • Extend/lengthen the existing turning lane • Add a dedicated turning lane at intersection • Extend/lengthen the existing lane • Redirect traffic i.e., replace exit ramp with entrance ramp from collector distributor to mainline lanes. • Restriping i.e., re-mark pavement lanes to add more narrow lanes
	Lane Drop	Where one or more traffic lanes are lost—typically at bridge crossings. Occurs on short ramps on interchanges	• Add auxiliary lane to connect an on-ramp and off-ramp • Extend/lengthen the ramp
	Inadequate Interchange/Ramp Capacity	Inability of freeway-to-freeway interchanges and ramps to handle high traffic volume merging and weaving. Occurs on short ramps, single-lane ramps, short deceleration lanes	• Extend/lengthen the ramp length • Extend/lengthen the acceleration and deceleration lanes • Add a dedicated turning lane at intersection • Ramp metering—install traffic signals at freeway on-ramps to control the rate of vehicles entering the freeway • Realign/improve interchange layout and add ramps • Widen lane width on ramp • Install new traffic signal • Add auxiliary lane to connect an on-ramp and off-ramp • Reduce speed limit on ramp • Install warning/advisory/navigational signs on ramps • Improve existing road signs to reduce confusion or to warn the traffic • Repaint pavement marking with fluorescent paint to separate traffic movement • Restriping i.e., re-mark pavement lanes to add more narrow lanes
	Steep Grade	Where steep uphill grade causes trucks to slow down causing delays to other traffic	• Add a passing lane on steep grades
	Steep Grade with Ramp Meter	Ramp metering on steep grades to regulate access to urban freeways resulting in queues and delays caused by slow-moving trucks.	• Remove ramp meter, i.e., remove traffic signal on ramp with steep grades • Relocate ramp meter, i.e., relocate traffic signal on ramp to improve effectiveness • Alter ramp metering operation, i.e., reprogram traffic signal operation on ramp to provide exclusive lanes to bypass queue at ramp meter • Modify median bull noses to facilitate turning movements

Table 31. (Continued).

	Constraint	Constraint Description	Improvements
Physical Constraints	Inadequate Turning Radii	Turning radius at edge intersections too tight to permit easy entry and exit by turning vehicles without encroaching on other lanes. Intersections – urban arterials; intermodal connectors	• Widen to improve turning radius • Add a dedicated turning lane at intersection • Modify median bull noses to facilitate turning movements • Widen and extend existing lane width • Widen to improve turning radius • Add a dedicated turning lane at intersection • Modify median bull noses to facilitate turning movements • Widen and extend existing lane width
	Inadequate Mainline Capacity	Traffic demand exceeds mainline capacity due to insufficient number of lanes to handle traffic volume. Urban Interstates/urban principal arterials.	• Install warning/advisory/navigational signs • Reduce speed limit on ramp • Provide alternative directions for alternative routes, e.g., use secondary roads • Improve existing road signs to reduce confusion or to warn the traffic • Repaint pavement marking with fluorescent paint to separate traffic movement • Restriping i.e., re-mark pavement lanes to add more narrow lanes • Use beacons, advisory signs, etc. to implement revisions in merging and diverging areas • Deploy technology to allow in-cab communication
	Inadequate Intersection Capacity	Traffic demand exceeds intersection capacity; may be caused by outdated traffic signals, poor signal timing, or no dedicated turn lanes	• Add a dedicated turning lane at intersection • Extend/lengthen the existing turning lane • Widen the lane width • Modify traffic signal phasing taking traffic volume in account • Install traffic signal at intersection • Upgrade existing traffic signal • Widen pavement shoulder • Extend existing turning lanes to accommodate traffic • Improve existing road signs to reduce confusion or to warn the traffic • Improve intersection layout to meet traffic demand and accommodate trucks • Add auxiliary lane to connect an on-ramp and off-ramp
	Insufficient Parking for Trucks	Inadequate parking facilities along highways and restrictions in central business districts	• Provide basic parking for trucks even if without amenities especially closer to urban areas • Widen and pave shoulders to allow trucks to park – especially close to urban areas
Operational Constraints	Steep Grade with Ramp Meter	Ramp metering on steep grades to regulate access to urban freeways resulting in queues and delays caused by slow-moving trucks	• Remove ramp meter, i.e., remove traffic signal on ramp with steep grades • Relocate ramp meter, i.e., relocate traffic signal on ramp to improve effectiveness • Alter ramp metering operation, i.e., reprogram traffic signal operation on ramp to provide exclusive lanes to bypass queue at ramp meter
	Poor Road Signage/Lack of Warning Signs	Poor road signage, i.e., graphics created to display information to highway users in order to warn or inform	• Improve existing road/navigational signs to reduce confusion or to warn the traffic • Provide warning/advisory and/or navigational signs
	Poor Traffic System Management	Lack of, or poor , traffic control system including a condition where signal timing does not meet traffic requirements	• Upgrade existing traffic signal to accommodate traffic demand • Install new traffic signal system • Modify signal phasing taking traffic volume into account • Synchronize closely placed traffic signals for traffic to receive right of way simultaneously during one or more intervals
	Lack of Traveler Information	Lack of or limited traveler information provided to trucks	• Improve existing or provide traveler information • Use variable message signs to provide traveler information
Regulatory Constraints	Truck Restrictions in Central Business District	Where regulatory controls restrict access to central business district during certain times of the day or restrict parking in certain sections	• Develop and implement loading comprehensive zone plan that considers truck delivery and pickup • Implement metered freight loading zones in designated areas • In high freight activity locations, add loading zone “hot spots” • Designate locations with on-street parking away from loading zones • Discourage peak-hour loading/unloading through increased parking violation fines during peak periods • Increase enforcement activities for automobiles parking in docking areas

the double-tracking of Union Pacific's Sunset Route from El Paso to Colton, California, were recognized as projects of national significance by virtue of their location within the rail network and their contribution to rail freight movement (*90*). Also, the Chicago Region Environmental and Transportation Efficiency (CREATE) program assembles a number of projects of importance to multiple railroads, Metra, and Amtrak in the Chicago area with the stated goals of not only reducing rail and motorist congestion, but also improving passenger rail service, enhancing public safety, promoting economic development, creating jobs, and improving air quality (*29*).

For railroads, deepwater ports, and inland waterways, the catalog of low-cost improvements that can be quickly implementable is difficult to develop for the following main reasons:

1. In most cases, operators of freight services over railroad networks, at railroad-owned network links, at port terminals, and along inland waterway networks are private firms answering to their shareholders, not Federal or state agencies. They have different funding criteria and market incentives from those more familiar to state transportation departments.
2. Estimating the "national value" of freight mobility debottlenecking is *terra incognita* for private network investors and operators. Benefit calculations for these firms would feature private returns, not social benefits or external economies and diseconomies.
3. Railways, ports, and inland waterways freight projects, especially those thought to exhibit "national value," are likely to be "high cost, multi-year" initiatives, rather than activities that are "low cost, quickly implementable" in scope.

A recent study (*45*) on the rail freight capacity identified the major rail bottlenecks within the rail network. Figure 29 shows the locations of some of the major bottlenecks and corridors. Table 32 shows the characteristics of some improvement programs and projects that are either under way or planned for these bottlenecks. These programs are joint public and private stakeholder cooperative initiatives with the primary objectives of reducing congestion and delays on rail and highways, improving efficiency in freight and passenger mobility, enhancing safety, and reducing air emissions.

Information gathered through literature reviews, interviews, and survey of stakeholders indicate that some of the most severe and persistent rail freight mobility constraints include the following:

- Outdated communication and signaling systems including signaling restrictions
- Switching inefficiency including conflicts for mixed-speed operation on single or dual tracks
- Inadequate sidings to accommodate train lengths
- Inadequate capacity of yards and port terminals.

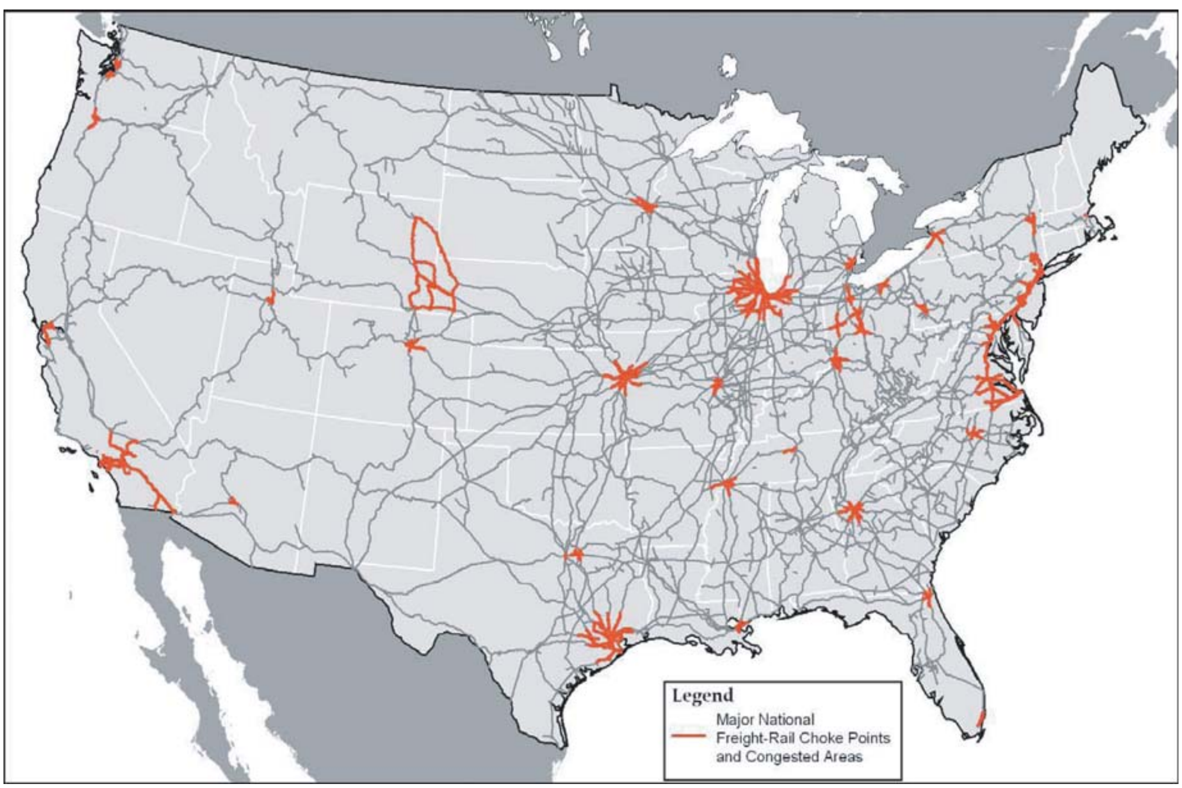


Figure 29. Major chokepoints in rail freight network (45).

Table 32. Characteristics of some improvement programs in freight rail system.

Corridor/ Bottleneck	Chokepoint Characteristics	Program Characteristics
Chicago (*29*)	• 6 Class I railroads • 1,200 trains a day (500 freight, 700 passenger) • 37,500 rail cars processed daily • 3,200 daily truck trips • 74 marshalling yards	CREATE Program • Federal/state/city/public-private partnership—$1.5 billion • 78 rail and highway capacity improvement projects, e.g., switches, interlocking, communication systems • Reduce delays to passenger and freight rail and enhance safety
Los Angeles (*90*)	• 2 Class I railroads and 4 short-line serving ports of Los Angeles and Long Beach • 6 major rail-truck intermodal transshipment yards • 3 inland railyards • Congestion at Los Angeles and Long Beach ports	Alameda corridor • Public-private partnership—$2.4 billion • 20-mile freight expressway connecting inland railyards to ports • Results in 35 train movements per day average • 200 at-grade crossings eliminated • Reduce congestion at Los Angeles and Long Beach ports
Seattle and Tacoma ports access (*90, 91*)	• Intermodal capacity constraints at Port of Seattle, Washington • Short switching leads crossing busy streets at grade; short staging tracks • Terminal access problems to Port of Tacoma • Inadequate yard capacity • Seattle to Portland freight/passenger train conflicts	FAST Corridor • Public-private coalition invested $568 million • Improve BNSF yard operations • Signal improvements • Add sidings to improve track capacity • Expand yard switching capacity • Carload consolidation facility
Houston region (*92*)	• Class I and regional railroads • 5 rail yards • Delays to road traffic at-grade crossings	Freight route consolidation project • $3.3 billion improvements to reduce congestion especially at highway-railway crossings • Construction of several grade separations • Improvements in capacity and railroad connectivity
NS Crescent Corridor (North Jersey to New Orleans) (*93*)	• Significant highway congestion along route • 20-30% of AADT are trucks • 2,200 miles • Serving 46 ports • Long-haul intermodal services • Decreasing mainline capacity due to: - Limitations on handling 286,000 lb - Railcar availability - Dispatching problems	• Multi State/Federal/Public-Private Partnership—$2 billion • Increase capacity of mainline and yards • Upgrade existing rail facilities—28 new and faster trains; new locomotive engines and rail cars; and new terminals • Reduce transit time by 24 hours between Hampton Roads, VA and Midwest • Divert 1 million (or 30%) trucks off highway every year
Heartland Corridor (Port of Norfolk to Midwest) (*93*)	• Currently, double-stack trains must take longer routes by way of Harrisburg, PA, or Knoxville, TN. • Delay to intermodal freight movement between the East Coast and the Midwest.	NS Heartland Corridor • Multi-state/Federal/public-private partnership – (VA Port Authority, NS railroad, VA, WV, and OH)—$311 million • Increase intermodal freight capacity • Tunnel clearances for high-speed double-stack intermodal service from major Atlantic port to Ohio and Chicago intermodal hubs • 200-mile route reduction • Reduced transit time by 24 hours between East Coast and Midwest • Reduced shipping costs by about $500 per cargo container
Mid-Atlantic Rail (*94*)	• 10-20% of AADT on I-95 corridor are trucks • 250 million tons of freight in and out of region annually • 100 million tons of freight through region annually • 27 trains per day North-South • Several choke points along corridor: inadequate connections between rail lines; congested grade crossings, stations and terminals; outmoded and inadequate information and communication systems	I-95 Coalition (VA, MD, DE, PA and NJ) • Multi-state $6.2 billion target investment over 20 years • 71 infrastructure and information system improvements

As noted in Table 32, rail capacity improvements generally require large capital investments and such projects do not satisfy the criteria for low-cost improvements. However, elements of such large improvement programs are amenable to low-cost actions and have significant improvements in freight mobility. Furthermore, these actions can be implemented anywhere on the rail network to address freight mobility constraints, especially at major choke points. The second step therefore is to identify improvements that can be implemented alone or as part of major improvements. For example, the CREATE program assembles a number of projects that are designed to improve freight and passenger train as well as highway traffic movements. Projects under this program that could be classified as low-cost improvements are:

- **CREATE Project EW-4: BRC/NS Signal Upgrade**—This project upgraded the Belt Railway Company of Chicago (BRC) and Norfolk Southern (NS) signal systems to power switches and signals along a segment of track. The result is increased train speed from 10 to 20 miles per hour; this segment now can handle twice the number of trains, an increase from 23 to 46 freight trains per day (*29*).
- **Deval Interlocking Replacement**—The Deval interlocking machine in Des Plaines, Illinois, where several rail lines cross was replaced to improve operations by allowing the operator to remotely view the entire interlocking area on a computer screen (*29*).
- **CREATE Project WA-5: Upgrade and Reconfigure Corwith Interlocking and Remote CN Corwith Tower**—This project installed a new signal bridge at Corwith Yard as part of CREATE improvements. The results are increased movements in and out of the yard and increased train lengths at the connection with NS and CSXT from 5,400 feet to 8,000 feet. Train speeds through the interlocking are increased, and the speed of interchanges between BNSF and its partner railroads is improved (*29*).

The examples of low-cost improvements described for the CREATE projects and similar actions that have been proven to be effective in addressing rail freight mobility constraints and have the potential for nationwide applicability are included in the catalog presented in Table 33. These actions are derived from applying the methodology to different possible scenarios focusing on those applicable to the top bottlenecks of the freight transportation system. The strategies are aligned to the constraints that they have been deployed to address.

7.2.3 Deepwater Ports and Inland Waterways

The occurrence of a freight mobility constraint at a deepwater port terminal or an inland waterway system is determined to a large extent by freight demand and capacity of the facility to handle existing demand. In identifying the deepwater ports that experience congestion and other freight mobility constraints, the volume of freight passing through each port measured by the tonnage of freight handled is used to indicate the probable severity of mobility constraints. Table 34 shows the ranking of the top 25 ports in the United States for 2008 (*95*). Figure 30 shows the locations of these ports and tonnage of freight handled based on 2006 data (*96*).

Table 33. Catalog of low-cost improvements for rail system.

	Constraint	Constraint Description	Improvements
Operational Constraints	Switching Conflicts/ Inefficient Switching	Inefficient and inadequate switching and conflicts causing delays to trains	• Upgrade or reconfigure interlocking—Interlocking is an arrangement of signal apparatus that prevents conflicting movements through an arrangement of tracks such as junctions or crossings.
			• Implement remote switching
			• Coordination of Class I operations with short-line/regional railroad operations to optimize joint operations and expedite switching traffic at interchanges.
	Outdated Communication and Signal System	Old and outdated communication and signaling systems	• Centralized Traffic Control System—use of electrical circuits in tracks to monitor locations of trains, allowing remote control of train movements from a central dispatching office.
			• Signal improvements – deploy advanced technologies to improve signaling system
			• Implement on-board and wayside defect detection and other advanced sensors
			• Implement trunked digital communications systems

Table 33. (Continued).

	Constraint	Constraint Description	Improvements
Physical Constraints	Inadequate Siding Capacity	Lack of, or inadequate, passing siding to allow efficient train movement	• Extend siding track to accommodate longer trains
			• Provide new siding track long enough to accommodate train lengths
			• Provide turnout to enable trains to be guided from one track to another at a railway junction
			• Realign tracks to ensure smooth ride and increased speed
			• Upgrade siding track to accommodate all trains using track
			• Provide connection tracks
			• Centralized Traffic Control System—use of electrical circuits in tracks to monitor locations of trains, allowing remote control of train movements from a central dispatching office.
	Inadequate Capacity of Yards and Port Terminals or Inefficient Yard Operations	Inadequate rail and port terminals as well as inefficiencies in terminal operations causing delays to trains and trucks	• Expand carload terminals to add capacity
			• Expand intermodal terminals to add more capacity
			• Maximize infrastructure and equipment utilization through cooperative competitor arrangements for port terminal operations
			• Coordinate operations with feeder services, e.g., short-line or regional railroads, to optimize joint operations
Physical Constraints	Inadequate Track Capacity	Physical characteristics of tracks to handle train traffic and causing delays to trains due to slow speeds and resulting increased trip time	• Maximize infrastructure and equipment utilization through route sharing and directional flows – two competitive company's routes coordinated and operated directionally
			• Advanced electronic inspection techniques to speed up inspection activities
			• Tie replacement to improve train speed
			• Track surfacing or putting the rails and track in a uniform plane (usually includes lining and gauging) is remedy to correct irregular track surface, with sags, low joints, bent rails, and short depressions and humps in the roadbed.
			• Improve crossing warning systems and make current passive crossings active
			• Provide turnout or switch – i.e., mechanical installation enabling trains to be guided from one track to another at a railway junction.
			• Realign tracks to ensure smooth ride and increased speed
			• Provide crossover – i.e., a pair of switches that connects two parallel rail tracks, allowing a train on one track to cross over to the other
			• Curve Superelevation – correct or provide superelevation in curves to enhance safe speed
			• Maintenance of way (MOW) – optimize scheduling of track work windows
			• MOW-seasonal "blitz" to coordinate multiple "out-of-face" projects with dedicated equipment and track forces
			• Relocate crew change points and re-schedule trains to improve safety, hours-of-service compliance, and customer service
Regulatory Constraints	Limited Funding/ Fear of Regulation	Lack of funding (public and private) to support and ensure efficient operation or expand capacity	• Remove capping of returns/provide incentives for investments
			• Investment tax credit
			• Encourage public-private partnerships
			• Provide access to public funding

Table 34. Top 25 ports in terms of tonnage (2008) (*95*).

Rank	Port Name	Domestic (thousand tons)	Foreign (thousand tons)	Total (thousand tons)	% of National Total
1	Port of South Louisiana, LA	112,550	111,437	223,987	8.7%
2	Houston, TX	65,808	146,400	212,208	8.2%
3	New York, NY and NJ	62,379	91,101	153,480	5.9%
4	Long Beach, CA	12,934	67,271	80,205	3.1%
5	Corpus Christi, TX	21,431	55,355	76,786	3.0%
6	New Orleans, LA	36,530	36,481	73,011	2.8%
7	Beaumont, TX	22,688	46,796	69,484	2.7%
8	Huntington-Tristate	69,335	0	69,335	2.7%
9	Mobile, AL	29,524	38,111	67,636	2.6%
10	Port of Plaquemines, LA	35,813	27,931	63,744	2.5%
11	Los Angeles, CA	6,875	52,913	59,788	2.3%
12	Lake Charles, LA	22,012	31,766	53,778	2.1%
13	Texas City, TX	13,896	38,710	52,606	2.0%
14	Baton Rouge, LA	35,909	15,901	51,810	2.0%
15	Duluth-Superior, MN and WI	30,333	15,009	45,342	1.8%
16	Norfolk Harbor, VA	7,707	36,886	44,593	1.7%
17	Baltimore, MD	12,454	30,959	43,413	1.7%
18	Pittsburgh, PA	41,837	0	41,837	1.6%
19	Tampa, FL	26,296	13,380	39,676	1.5%
20	Paulsboro, NJ	12,482	23,870	36,352	1.4%
21	Valdez, AK	35,967	0	35,967	1.4%
22	Savannah, GA	1,839	33,555	35,394	1.4%
23	Pascagoula, MS	9,453	24,137	33,590	1.3%
24	Philadelphia, PA	11,960	20,323	32,283	1.3%
25	Port Arthur, TX	10,005	21,748	31,753	1.2%

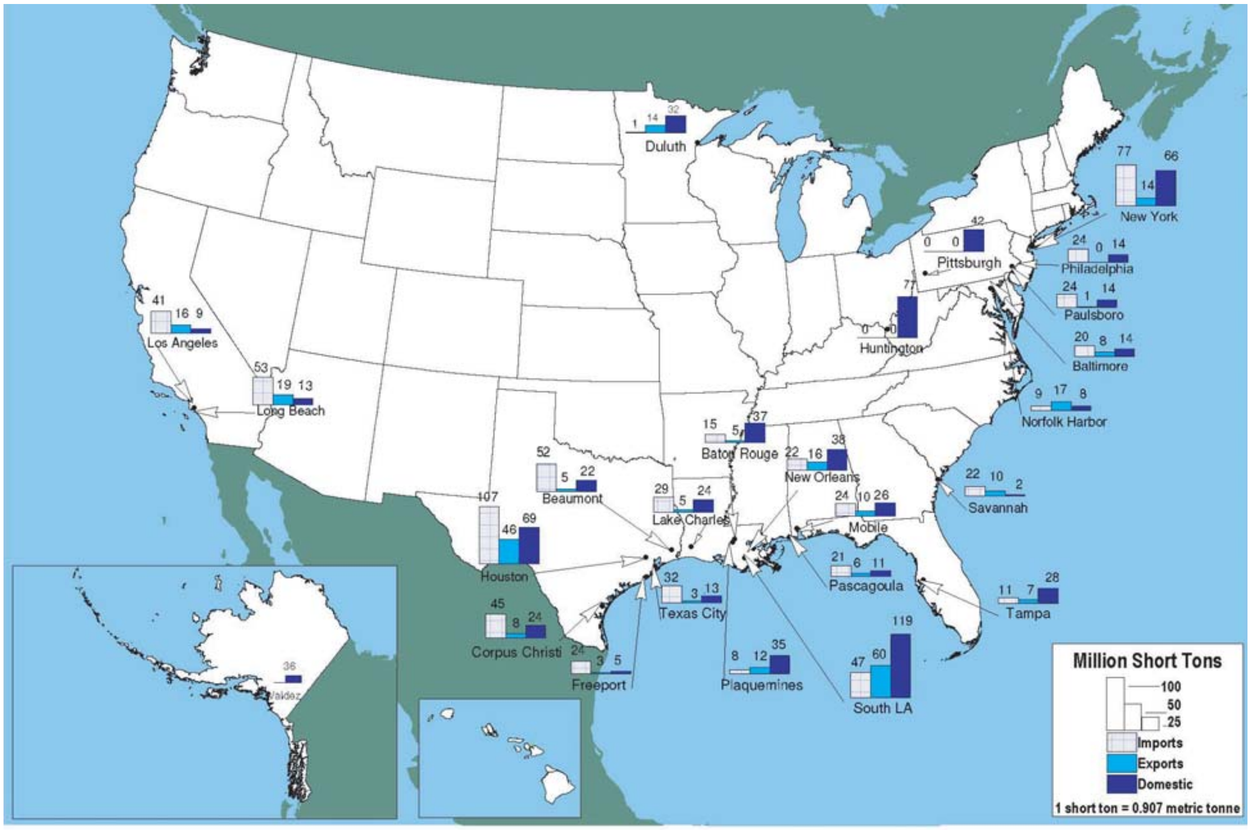
As noted earlier, the following freight mobility constraints are identified as often encountered at the port terminals:

- Inadequate terminal capacity
- Physical barriers to rail operations
- Empty container storage and movement
- Inadequate local street and highway access from terminal
- Inadequate waterway or channel depths
- Inefficient terminal layout or terminal operations
- Loss of communication on inland waterways in rural areas.

These constraints occur "on the terminal" and "outside the gate." Actions satisfying the criteria of low-cost and quickly implementable improvements and which might be of national significance would include operational/technology and regulatory oriented actions. Freight mobility improvement projects and programs for deepwater ports and inland waterways generally involve large capital investments that invariably are funded by private industry. It is also recognized that each port is unique where improvements at one location may not necessarily yield similar results at another port.

Table 35 presents examples of programs that have been implemented to improve freight mobility and reduce congestion at some deepwater ports. These programs are primarily operational or technological actions designed to reduce congestion and delays to trucks and improve efficiency in container movements to and from the ports. Some programs are incentive-type programs designed to influence demand and consequently reduce the impacts on congestion. These strategies are of national value because, potentially, they can be implemented at any port in the country with similar results.

Table 36 shows the list of low-cost improvements to address freight mobility constraints at deepwater ports and inland waterways. These actions are derived from the database of implemented projects that underlies the methodology.



Source: U.S. Army Corps of Engineers, *2006 Waterborne Commerce of the United States, Part 5, National Summaries* (New Orleans, LA: 2007), Table 5-2.

Figure 30. Top 25 U.S. ports by tonnage—2006 **(96).**

Table 35. Examples of programs with low-cost components.

Program	Summary of Program	Where Implemented
Incentive-based congestion pricing to encourage off-peak movements, e.g., PierPASS (*38*)	The PierPASS OffPeak program is a private-sector initiative, incentive-based program to shift movement of international containers from peak weekday hours to evenings and weekends.	Ports of Los Angeles and Long Beach, California
Incentive-based program to shift freight from trucks to rail, e.g., ExpressRail (*97*)	ExpressRail—incentive program to encourage shippers to use rail rather than trucks for moving cargo through the Port. The program pays $25 per container shipped by rail to any ocean carrier that increases the number of containers it transports over its 2008 levels.	Port Authority of New York/New Jersey
Maximize infrastructure and equipment utilization through cooperative competitor arrangements, e.g., Chassis pool (*98*)	Hampton Roads Container Pool II (HRCP-2), shipping lines provide chassis for the pool which are available for use by truck drivers who do not have to switch chassis to haul for different shipping lines.	Norfolk, Virginia
Maximize infrastructure utilization through cooperative competitor arrangements, e.g., Rail Yard Cargo Shift (*99*)	Union Pacific Railroad is shifting its domestic intermodal container business from the Port of Seattle's Argo Rail Yard to Tacoma, renting 10 acres of land across from the Port of Tacoma's South Intermodal Yard.	Ports of Seattle and Tacoma, Washington

Table 36. Catalog of low-cost improvements for deepwater ports.

	Constraint	Constraint Description	Improvements
Operational Constraints	Inefficient terminal layout/gate operations	Layout of terminal yard restricting inefficient operations; inefficiencies of terminal gate operations causing congestion and delays at the gates	• Extend gate operating hours
			• Implement congestion pricing to discourage truck activity during peak periods (e.g., PierPASS)
			• Incentive-based program to shift freight from trucks to rail (e.g., ExpressRail)
			• Implement truck appointment system
			• Implement automated yard marshalling and inventory control
			• Utilize joint inspection facilities
			• Establish flexible labor shifts
			• Develop partnerships among stakeholders to accommodate uneven demand cycles
			• Utilize wireless communications to facilitate proper storage, ship operations, gate operations
			• Maximize infrastructure and equipment utilization through cooperative competitor arrangements (e.g., Chassis pool)
			• Deploy technologies to utilize high-speed gates/fast lane using paperless checking
			• Use multi-pick cranes
	Poor traffic control at terminal yard/gates-roadway connections	Lack of, or poor, traffic management system on road access to port terminals, e.g., where signal timing does not meet traffic requirements	• Implement traffic management system techniques at roadway connectors to ports (e.g., synchronizing traffic lights; improving signal phasing)
			• Upgrade existing traffic signal to accommodate traffic demand
			• Modify signal phasing taking traffic volume into account
	Inadequate rail intermodal connector capacity	Inadequate capacity of rail connectors to handle train traffic	• Use fast rail shuttles
			• Integrate maritime and rail movements
			• Off-dock container yards
			• Partnership to reduce passenger/freight rail use conflicts
Regulatory Constraints	Labor laws and restrictive contractual limitations	Restrictive labor laws and contractual agreements that adversely impact labor supply	• Negotiate training terms and conditions to increase skills and trained labor supply
	TWIC requirements and lack of card-reading equipment	Implementation of security and safety measures	• Upgrade card readers
			• Use existing off-the-shelf software packages for card readers
Physical Constraints	Inadequate capacity of terminal yard/gates	Inadequate capacity of terminal yard to meet demand	• Locate secured inspection areas outside major traffic areas
			• Terminal reconfiguration to add capacity
			• Maximize infrastructure utilization through cooperative competitor arrangements (e.g., Rail Yard Cargo Shift)

CHAPTER 8

Conclusions and Suggested Research

8.1 Conclusions

This project developed standardized descriptions of the dimensions of the freight transportation system, defined freight mobility constraints in a multimodal context, developed criteria for low-cost and quickly implementable improvements to address freight mobility constraints, and developed a software application tool to help decision makers in evaluating freight mobility constraints and selecting appropriate improvements. The tool is backed by a database of improvement projects for highway, rail, and deepwater ports and implemented by different agencies.

Freight mobility is constrained not only by physical infrastructure inadequacies but also by operational, regulatory, policy, technological, and financial limitations. The capacity of the existing freight transportation system can be increased through innovative operational strategies, performance-improving regulatory and policy changes, and low-cost capital improvements.

Definition of Freight Mobility Constraint

A freight mobility constraint can be defined as "a physical or infrastructure deficiency, regulatory requirement (Federal, state, or local), or operational action that impedes or restricts the free flow of freight either at the network level or at a specific location." Mobility constraints increase costs, contribute to system inefficiencies, and delay on-time freight delivery. The three main types of constraints are:

- *Physical Constraints*—any geometric or infrastructure conditions that constrain freight operators from operating at designed, safe speeds and within legally required parameters. Examples include inadequate capacity of the transportation system to meet traffic demand (e.g., mainlines, interchanges, rail sidings, port terminals) and geometric restrictions or limitations affecting safe and efficient mobility.
- *Operational Constraints*—practices, processes, events, or occurrences that constrain optimal throughput, and efficient operating conditions. Examples include poor signal phasing, port gate processes, technological limitations, outdated signaling systems, and inadequate traveler information.
- *Regulatory Constraints*—Federal, state, or local regulatory requirements that, while intended to provide an environment for safe and secure operation, have unintended consequences that restrict the flow of freight through the system. Examples include safety and security requirements, truck restrictions, zoning policies, air quality restrictions, and labor contractual limitations.

The predominant type of freight mobility constraint (physical, operational, or regulatory) depends on the primary mode of freight movement. Regulatory restrictions (in particular Federal, state, and local land use and environmental laws and regulations) and operational limitations (including technological limitations/inadequacies) are the most common types of mobility constraints affecting all modes.

Criteria for Low-Cost and Quickly Implementable Improvement

Although many innovative, low-cost efforts are being implemented by public and private agencies, there are no unique criteria to define what constitutes a low-cost improvement directed to enhance freight mobility. A "low-cost and quickly implementable" improvement to address freight mobility constraints may be defined as:

> an action that modifies existing geometry and operational features of the freight transportation infrastructure system and that can be implemented within a short period without extended disruption to traffic flow. Such an improvement may be physical, operational, or regulatory, as long as it enables greater throughput from existing facilities. These actions may be spot (or location-specific) improvements or may be limited to short sections of the

physical infrastructure. Likewise, they may be specific to a given supply chain process point, regulation, or mode; they may also affect multiple modes of freight movement. Furthermore, low-cost improvements do not involve massive reconstruction of infrastructure that usually takes many years to complete.

Mode-specific criteria for low-cost, quickly implementable improvements to address freight mobility constraints may be as follows:

- *Highways*—a low-cost and quickly implementable improvement does not require special programming, environmental clearances, or right-of-way acquisition and is within budget limitations, enabling implementation at a district level. A low-cost improvement project is typically a spot improvement and generally costs $1 million or less, and is considered "quickly implementable" when it can be completed in 1 year or less.
- *Railroads*—a low-cost and quickly implementable improvement project depends on the category of the railroad. For a short-line railroad, a low-cost improvement project is one that is less than $500,000 and able to be completed in less than 6 months. For a regional railroad of modest size, projects costing less than $2 million and that could be completed within a year would fit the criteria. For a Class I railroad, the cost would be $1 million to $10 million and the project could be completed within 2 years.
- *Deepwater Coastal Ports and Inland Waterways*—low-cost improvements are typically economic-incentive-based programs that influence demand, changes in operations and processes (including the use of advanced technologies), and projects that encourage modal shift. Physical low-cost improvements are coordinated with highway and rail improvements both within and outside the terminal. A low-cost and quickly implementable improvement across both deepwater ports and inland waterways is defined as costing up to $1 million and able to be completed within 2 years.

The type of improvement is not determined by the type of constraint. Operational improvements can be used to address physical constraints and vice versa. Similarly, regulatory and policy actions can be implemented to remove operational and physical constraints. Policy-type improvements are considered under the regulatory type, while economic-based actions that affect price and market-based solutions are classified as operational improvements. These definitions are generic, and while physical improvements are quite distinct, certain types of improvements could fit either regulatory or operational categories.

Methodology

A major output of this research is a methodology that decision makers can use to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and regulatory or public policy actions designed to enhance freight mobility by addressing identified constraints. The methodology is embodied in a computer-based application tool (available on the CD-ROM bound into this report) where decision makers make selections to define the constraint and select possible actions to address it based on previously implemented improvements elsewhere. The software is designed with a wizard-style user interface that facilitates navigation through the program. The user can also view sample projects where the actions have been implemented or proposed. The tool is backed by a database of information on historical low-cost improvements.

Catalog of Improvements

The tool was applied to develop a catalog of low-cost actions or classes of actions that can be quickly implemented to address freight-system mobility constraints especially along corridors or at locations that impact freight mobility at a national level. The theme in developing the catalog of actions was to identify proven low-cost improvements that have the potential to enhance freight mobility to noticeable extents even though such actions may not by themselves necessarily remove the constraint entirely. The catalog of improvements targets locations or corridors where major constraints within each modal freight transportation network occur. Improvements presented in the catalog are generic, however, implementation at a particular location would require consideration of specific site characteristics and operational practices. Similarly, given the uniqueness of each deepwater port, an effective action at one port may not necessarily be effective at another port.

8.2 Recommendations for Further Research

The methodology is data driven and therefore, to serve a useful purpose, the database needs to remain dynamic and be continuously updated. It is therefore recommended to develop a mechanism to keep updating and adding new actions to the database as additional information becomes available. No such mechanism currently exists to collect and process low-cost freight mobility constraint improvement projects. Research is needed to develop a mechanism for collecting and reporting project data to update the database on a continuous basis. A standardized process similar to the Highway Performance Monitoring System is suggested to define, describe, or measure low-cost freight mobility constraint improvement projects. A web-based application is recommended to facilitate the process.

To enhance the usefulness of the tool and to facilitate updates to the database, it is further recommended that the tool be converted to a web-based software application tool once sufficient data are included in the database. A collaborative effort among modal stakeholders will be needed to develop and utilize the data collection mechanism and to facilitate continuous update of the database. Such a mechanism will include a feedback screen to capture strategies selected by policy/decision makers to resolve mobility issues. This information will contribute to the database and add intelligence to the application.

In its current form, the tool is developed as standalone software that is available on CD-ROM or via download from the TRB website (www.trb.org). It is also suggested to the extent possible, the geographic specificity of the locations of implemented low-cost improvement projects be included so that the tool can be converted to a GIS web-based application to improve its utility.

The methodology was developed acknowledging that it would be integrated into the standard Project Development Process, which each state DOT and MPO is required to have in order to use state or Federal funds to implement such projects. Research is needed to guide the integration of the tool with the project development process.

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Acronyms

3PLs	3rd Party Logistics Providers
AAA	American Automobile Association
AADT	Annual Average Daily Traffic
AADTT	Annual Average Daily Truck Traffic
AAPA	American Association of Port Authorities
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACI	Automatic Car Identification
AEI	Automatic Equipment Identification
AIWW	Atlantic Intracoastal Waterway
ATA	American Trucking Associations
ATRI	American Transportation Research Institute
AWO	American Waterway Operators
BLS	Bureau of Labor Statistics
BNSF	Burlington Northern Santa Fe Railway
BRC	Belt Railway Company of Chicago
Caltrans	California Department of Transportation
CAD	Computer Aided Dispatch(ing)
CB	Citizens Band (Radio)
CBD	Central Business District
CBO	Congressional Budget Office
CLM	Car Location Message
CREATE	Chicago Region Environmental and Transportation Efficiency Program
CS&I	Communications, Signaling, and Information
CSCMP	Council of Supply Chain Management Professionals
DHS	Department of Homeland Security
DOD	Department of Defense
DOT	Department of Transportation
DST	Double-Stack Train
dwt	Dead Weight Tonnage
EJ&E	Elgin, Joliet, and Eastern Railway
EPA	Environmental Protection Agency
FAF	Freight Analysis Framework
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FPM	Freight Performance Measurement
FRA	Federal Railway Administration
FSC	Freight Stakeholders Coalition

GAO	Government Accountability Office
GDP	Gross Domestic Product
GIS	Geographical Information System
GIWW	Gulf Intracoastal Waterway
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HPMS	Highway Performance Monitoring System
HOV	High Occupancy Vehicle
IHS	Interstate Highway System
IPO	Initial Public Offering
IRPT	Inland Rivers, Ports, and Terminals, Inc.
IT	Information Technology
ITC	Investment Tax Credit
ITS	Intelligent Transportation System(s)
JIT	Just-in-time
LCIAT	Low-Cost Improvement Analysis Tool
LNG	Liquefied Natural Gas
LOS	Level of Service
LTL	Less than Truckload
MARAD	Maritime Administration
MOW	Maintenance of Way
MPO	Metropolitan Planning Organization
MTS	Marine Transportation System
NCHRP	National Cooperative Highway Research Program
NHPN	National Highway Planning Network
NHS	National Highway System
NITL	National Industrial Transportation League
NN	National Network
NS	Norfolk Southern
O-D	Origin-Destination
PPP	Public-Private Partnerships
PSI	Present Serviceability Index
PTC	Positive Train Control
RFID	Radio Frequency Identification
RITA	Research and Innovative Technology Administration
RO/RO	Roll-on/roll-off
ROI	Return on Investment
SCOD	AASHTO's Subcommittee on Design
STB	Surface Transportation Board
TEU	Twenty-Foot Equivalent Unit
TIP	Transportation Improvement Program
TL	Truckload
TRB	Transportation Research Board
TWIC	Transportation Worker Identification Credential
U.S.	United States
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDOT	United States Department of Transportation
VACIS	Vehicle and Cargo Inspection System
v/c	Volume/Capacity Ratios
VMT	Vehicle Miles Traveled

APPENDIX A

Methodology User Guide

Welcome to the Low-Cost Improvement Analysis Tool (LCIAT)

This document is a guide to using the methodology for identifying and evaluating low-cost capital, operational, and regulatory actions to address freight mobility constraints for the primary modes: highway, rail, and deepwater ports/inland waterway. This User Guide is designed to help you use the Low-Cost Improvement Analysis Tool (LCIAT). The guide describes how the model works, and how you can use it to accomplish your objectives.

The Analysis Tool

Freight mobility is constrained not only by physical infrastructure inadequacies but also by operational, regulatory, policy, technological, and financial limitations. Federal, state, and local transportation agencies' ability to invest in system expansion and new system technology has been significantly constrained by inadequate revenue. There are opportunities to increase the capacity of existing freight networks through innovative operational strategies, performance-improving regulatory and policy changes, and low-cost capital improvements. These factors have significantly increased interest in addressing freight mobility constraints through implementation of low-cost physical, operational, and regulatory improvements.

The methodology developed in this project provides a structured approach to analyze freight mobility constraints and identify appropriate low-cost improvements that can be quickly implemented. The methodology considers highway, rail, and water modes of freight movement. The methodology is encapsulated in a software application tool designed to help private- and public-sector decision makers to identify, categorize, and evaluate quickly implementable, low-cost capital, operational, and regulatory (or public policy) actions to reduce mobility constraints in the freight transportation system.

Definition of Freight Mobility Constraint

In this methodology, a freight mobility constraint is generally defined as:

> A physical or infrastructure deficiency, regulatory requirement (Federal, state, or local), or operational action that impedes or restricts the free flow of freight either at the network level or at a specific location.

Mobility constraints increase costs, contribute to system inefficiencies, and delay on-time freight delivery. Examples of the three types of constraints are:

- *Physical Constraints*—inadequate capacity of the transportation system (e.g., mainlines, interchanges, port terminal connectors, rail sidings); geometric restrictions or limitations affecting efficient mobility
- *Operational Constraints*—events or occurrences that constrain legal operating speeds; poor signal phasing; terminal switching inefficiency; restricted terminal gate operating hours; inadequate traveler information
- *Regulatory Constraints*—safety and security requirements; truck restrictions; land use controls that restrict facility expansion; air quality requirements; labor contractual limitations.

Criteria for Low-Cost Improvements

A low-cost improvement that can be implemented quickly is:

> An action that modifies existing geometry and/or operational features of the freight transportation system and that can be implemented within a short period of time without extended disruption to traffic flow. Such an improvement may be physical, operational, or regulatory, as long as it enables greater throughput from existing facilities. These actions may be spot (location-specific) improvements or may be limited to short sections of the physical infrastructure. Likewise, they may be

Table A-1. Key features of low-cost and quickly implementable improvements.

Mode	Characteristics of Low-Cost Actions	Quickly Implementable
Highway	• Less than $1 million • Spot or location-specific improvements • No environmental clearances necessary • No right-of-way acquisition • No special programming required • Implementation at district lowest operation unit level (limited direct HQ oversight)	Less than 1 year
Rail	• Class I railroad – $1 million to $10 million	Less than 2 years
	• Regional railroad – less than $2 million	Less than 1 year
	• Short-line railroad – less than $500,000	Less than 6 months
Deepwater Ports & Inland Waterways	• Less than $1 million • Essentially incentive-based programs to influence demand and changes in operational practices, and technology deployments • Physical improvements coordinated with highway and rail projects within and outside the port terminals at links serving ports – location-specific actions • Uniqueness of each port acknowledged	Less than 2 years

specific to a given supply chain process point, regulation, or mode; they may also affect multiple modes of freight movement. Low-cost improvements do not involve massive reconstruction of infrastructure that usually takes many years to complete.

Key features of the criteria are summarized in Table A-1.

Framework of Methodology

The methodology is designed to be a simple application tool where decision makers make selections to define the constraint and select possible actions to address it based on previously implemented improvements elsewhere. The user can review the characteristics of examples where the actions had been implemented or proposed. Examples are intended to validate improvements and to guide users in making suitable selections. The methodology is designed to be data driven where the database of implemented improvements can be updated and expanded as new project information becomes available. The overall framework of the methodology is depicted in Figure A-1.

About this Program

LCIAT is a Microsoft® Windows application that allows the user to characterize freight mobility constraints on the highway, rail, or deepwater ports and inland waterway modal systems and select suitable low-cost improvements to address them. Figure A-2 shows the flash screen of the program.

The program also allows the user to compare alternative improvement options and to view details of examples of imple-

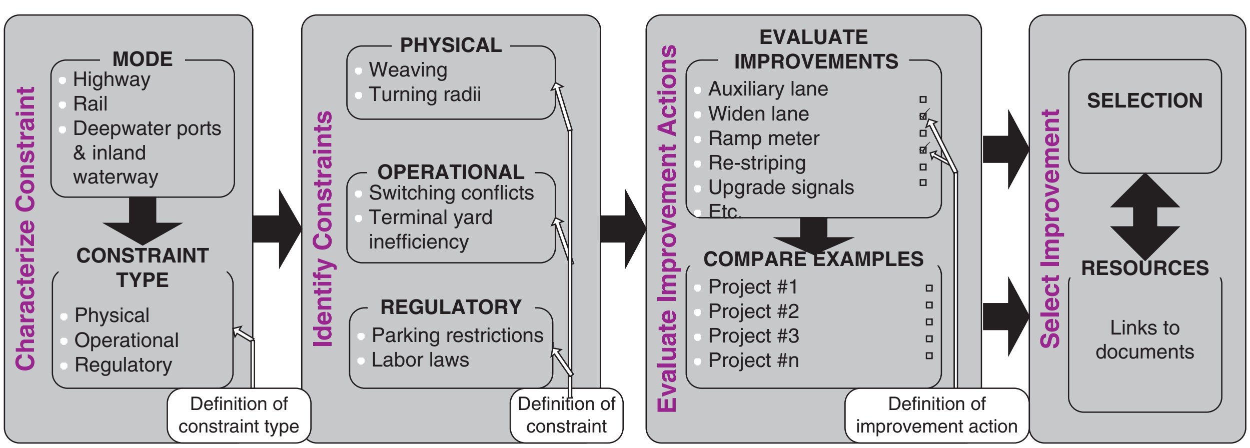

Figure A-1. Framework of the methodology.

Figure A-2. LCIAT flash screen.

mented low-cost improvement projects that address specific constraints. The program offers the user the option to use the wizard-style interface to navigate through the program using the "Next" and the "Back" buttons or query the database directly based on user-designed criteria.

The tool is entirely data driven where only information available in the database can be selected or displayed. The database was populated with data on implemented low-cost improvement projects. The data were gathered from state DOTs, railroad companies, and deepwater port terminal and inland waterway operators. The database can be updated as new data are gathered.

System Requirements

The following software must be installed to your computer:

- Microsoft .NET Framework 2.2
- Microsoft Data Access Components (MDAC) 2.8

Both are included on the program CD and can also be downloaded from the Internet.

Hardware System Requirements:
- CD-ROM drive
- 1 GB RAM
- 1 GHz processing speed
- 100 MB of hard drive space

Operating System Requirement:
Windows 2000, Windows XP (Professional or Home Edition), or Windows Vista software.

Installation

The CD containing the software application includes an executable program. To install and run the program:

1. Download or copy the .zip file from the CD into the subdirectory;

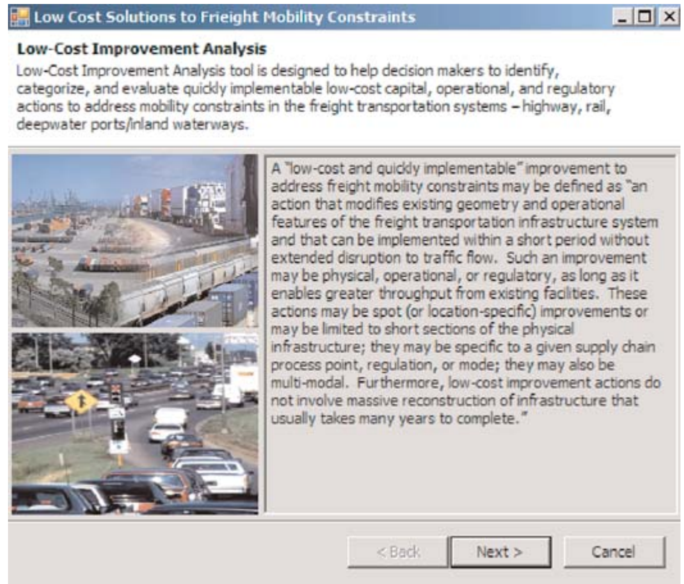

Figure A-3. Introductory window.

2. Unzip the contents of the .zip file;
3. Double click on the file named "setup.exe" to install the program;
4. Designate or create a sub-directory on your computer where the software will be installed (or it will be installed in C:\Program Files\Battelle\Low Cost Improvement Analysis Tool); and
5. Double click on the file named **"LCIAT.exe"** to start the program.

Running the Program

Figure A-3 shows the introductory screen that states the purpose of the tool (top window) and defines low-cost and quickly implementable improvements (lower window).

Wizard vs. Query

The program allows the user to select the desired approach to running the program (Figure A-4). Two options are available. The wizard approach allows the user to characterize the constraint under consideration and then select from a list of improvements that can be used to address that constraint based on experiences elsewhere. The query approach allows the user to search the database of projects based on user-defined criteria without having to navigate the entire program. The steps in using these two approaches are described in the following sections.

Wizard—Mode Selection

When using the wizard approach, the next screen (Figure A-5) allows the user to select the freight transportation mode of interest and the subcategory under the selected mode:

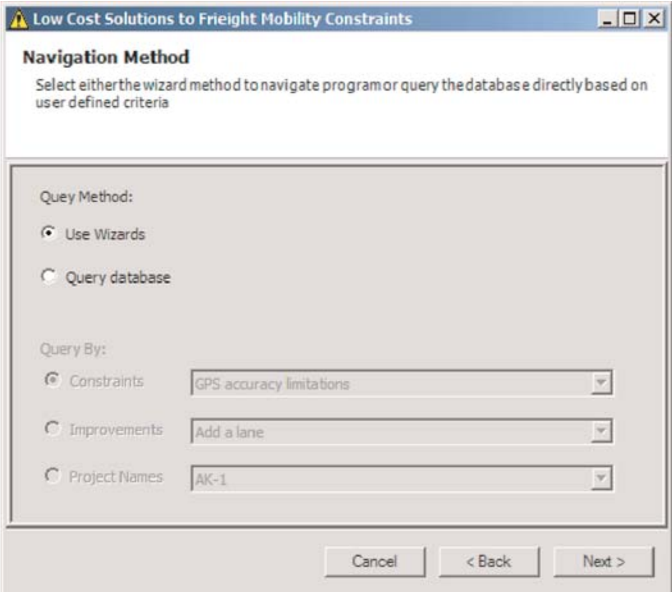

Figure A-4. Navigation method.

- **Deepwater ports and inland waterways –** subcategories are "on terminal," "outside the fence," and "waterside."
- **Highways** – subcategories are the major functional classes of the highway system – e.g., Interstates, urban and rural principal arterials, and local roads.
- **Railroads –** subcategories are Class I, regional, and local operators.

Wizard—Constraint Evaluation

Once the mode and the subcategory are selected, the next screen displays the possible locations where freight constraints on the modal network can occur based on information contained in the database (Figure A-6). Depending on the loca-

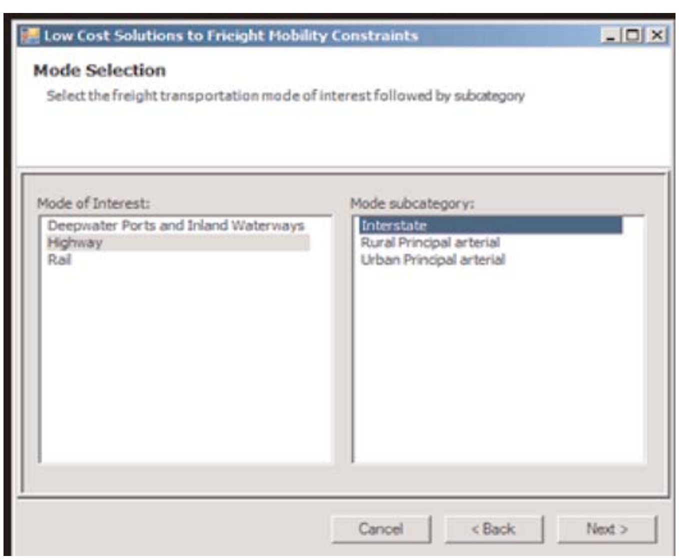

Figure A-5. Mode selection.

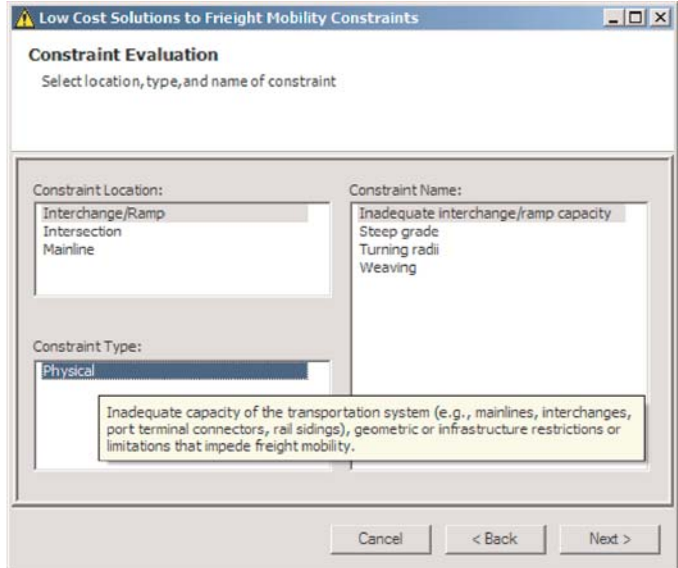

Figure A-6. Constraint evaluation.

tion of the constraint on the modal network selected, the corresponding examples of constraints organized by type are displayed on the right-hand side of the screen. Clicking on a different type of constraint in the window titled "Constraint Type" (in the lower left section of the screen) displays the corresponding examples of constraints in the window to the right. This feature allows the user to explore the various options depending on the type of constraint.

Moving or hovering the cursor over each of the constraint types—physical, operational, and regulatory (lower left window)—or over the corresponding constraints (in right window) displays the definitions in popup windows. These definitions are provided to guide the user to evaluate the constraints properly.

Wizard—Improvements Selection

The top window in the next screen displays the criteria for "low-cost and quickly implementable" improvements specific to the mode selected. The lower windows display the types of improvements (physical, operational, regulatory) and the corresponding list of improvement options aligned to the constraint selected on the previous screen. The list represents improvements that have been implemented elsewhere to address the constraints identified in the previous screen. The improvements are also organized by type of improvement (physical, operational or regulatory). For example, Figure A-7 shows the list of physical improvement options to address the constraint selected on the previous screen.

Wizard—Evaluating Improvement Projects

By clicking the improvements of interest, the user can go to the next screen to view and compare details of projects that have

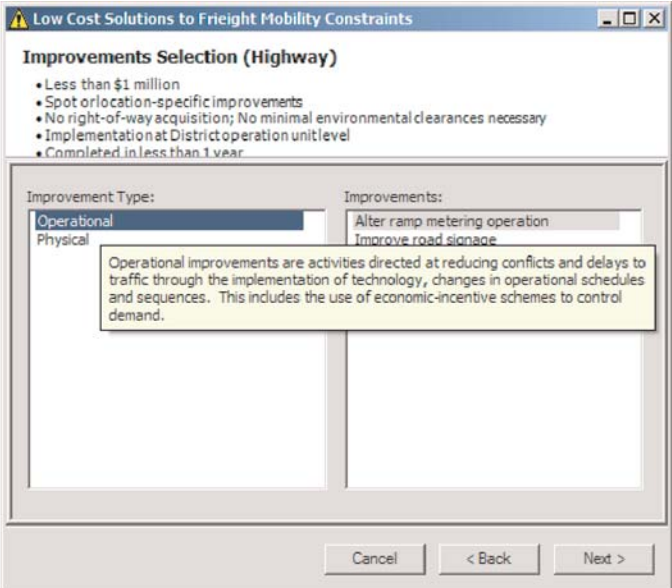

Figure A-7. Improvement selection.

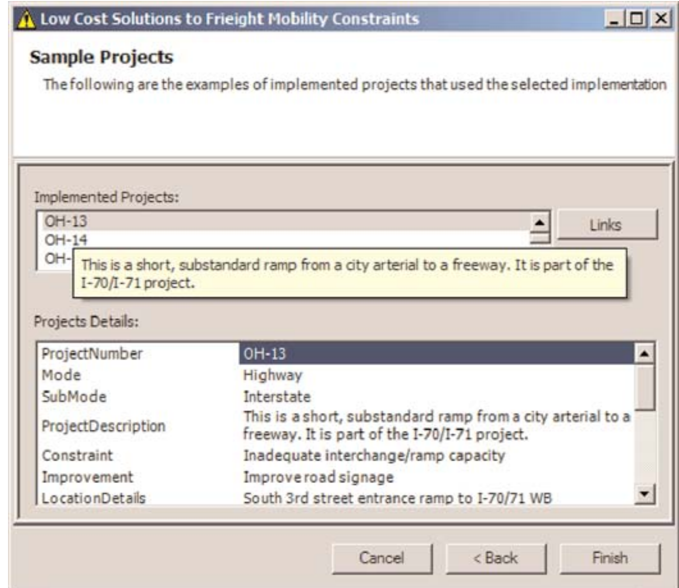

Figure A-8. Evaluation of options.

been implemented to address the particular constraint. Multiple selections are possible by holding down the "CTRL" key.

The middle window on this screen (Figure A-8) shows the list of assigned numbers for implemented improvements contained in the database. Moving the cursor over the project number in the middle window displays the description of the project as shown in Figure A-8.

The lower window on this screen displays the hierarchy of selections made on the previous screens that led to the applicable projects. This window also displays other project details such as descriptions of the project, cost, duration, performance measures, location, and lessons learned. The user evaluates the selected option by comparing the details of the projects.

Wizard—Links

For each project, a link is provided to relevant project documents and other sources of further information. Clicking on the "links" displays the document containing detailed information on the project of interest (Figure A-8).

Query—Search Criteria

This approach allows the user to select the database query criterion (Figure A-4). Clicking "Next" displays the list of projects satisfying the condition (Figure A-8). As for the wizard approach, the user can then view and evaluate the projects and also access the sources of detailed information by clicking on the "links" button.

Ending Program

Regardless of which approach is being used, clicking on the "Cancel" button takes the user back to the approach selection screen (Figure A-2). The rationale is to allow the user to begin another search, if desired. Clicking on the "Finish" button ends the program.

Additional Information and Technical Support

Questions about the tool can be addressed to

Dr. William C. Rogers
202-334-1621
WRogers@nas.edu
Senior Program Officer
National Cooperative Freight Research Program
Transportation Research Board
500 Fifth Street NW
Washington, DC 20001

Dr. Edward Fekpe
fekpee@battelle.org
614-424-5343
Research Leader
Battelle
Transportation Division
505 King Avenue
Columbus, Ohio 43201

APPENDIX B

Annotated Bibliography

Highways

Federal Highway Administration. *Traffic Bottlenecks: A Primer—Focus on Low-Cost Operational Improvements.* U.S. Department of Transportation, Washington, D.C. 2007.

This document describes highway bottlenecks and investigates potential near-term and low-cost construction to alleviate them. It defines bottleneck, explains the different types of freeway bottlenecks, and also explains their contribution to congestion. The report then provides 12 operational remedies based on information gathered through interviews and case studies. It also provides examples of how agencies deal with bottlenecks.

Cambridge Systematics Inc. and Battelle. An Initial Assessment of Freight Bottlenecks on Highways. White Paper prepared for Federal Highway Administration Office of Transportation Policy Studies. Washington, D.C. 2005.

This White Paper attempts to provide a way to identify and quantify highway bottlenecks that delay trucks and freight movement. This paper focuses on the impacts and cost of highway bottlenecks on truck freight shipments. It describes highway bottlenecks defined by three features: type of constraint, type of roadway, and type of freight route. It also explains the impact that congestion has on the national freight system capacity and performance.

Cambridge Systematics Inc. Ohio DOT Ohio Freight Mobility, Access, and Safety Strategies. Project report prepared for Ohio DOT. May 2006.

This report describes recent studies on the movement of freight in Ohio by trucks and describes the various types of bottlenecks. The document assesses the impacts of future change and makes recommendations to deal with changing demands and to improve Ohio's existing freight corridors. It also identifies short-range improvement strategies in Columbus and Cincinnati, many of which are capital and operational improvements.

Burke, N., T.H. Maze, M.R. Crum, D.J. Plazak, and O. Smadi. Dedicated Truck Facilities as a Solution to Capacity and Safety Issues on Rural Interstate Highway Corridors. In *Transportation Research Record 2008*. Transportation Research Board of the National Academies, Washington, D.C. 2007, pp. 84–91.

The paper presents a specific case study conducted on high truck volume rural interstate highway segments to illustrate the safety, operational, and productivity benefits to constructing dedicated truck facilities in order to separate trucks from other vehicles. The analysis used the Highway Economic Requirements System (HERS) software. This paper explains what a dedicated truck facility is and how it benefits and improves safety and traffic flows.

Government Accountability Office. *Freight Transportation: National Policy and Strategies Can Help Improve Freight Mobility*, GAO-08-287, Government Accountability Office Washington, D.C. Jan. 2008.

This report explains how the movement of goods involves a wide array of public and private stakeholders and provides an example of goods movement from port of entry to the consumer. This report also describes 3 factors that significantly contribute to constrained freight mobility: growing freight, capacity restraints, and inefficient use of infrastructure. It presents challenges that public planners face when advancing freight improvement projects. The report also provides examples and case studies on improving or enhancing freight mobility in areas of enlarged capacity and infrastructure use.

Latham, F.E. and J. Trombly. *Low Cost Traffic Engineering Improvements: A Primer.* Report No. FHWA-OP-03-078. Federal Highway Administration, Washington, D.C. April 2003.

This report presents low-cost traffic engineering improvements to improve safety and congestion, including types of actions, costs, and benefits. Much of the results presented in this report were derived from interviews with transportation agencies and review or research of literature. This report gives a baseline for describing low-cost improvements as opposed to expensive capital improvements. It also presents numerous examples and case studies of actions implemented to alleviate congestion and bottlenecks. Most of these improvements are operational and physical improvements.

American Highway Users Alliance. Unclogging America's Arteries: Effective Relief for Highway Bottlenecks 1999–2004. American Highway Users Alliance. Washington, D.C. 2004.

This report addressed three objectives:

1. Identify the worst traffic bottlenecks in the United States, recognizing that some cities may have more than one. Focus in detail on those bottlenecks that create the longest delays for travelers, limiting consideration to interstate highways and other freeways.
2. Estimate the benefits to travelers and the environment by removing the bottlenecks, based on the actual improvement plans if they exist. The benefit estimation is driven by a set of assumptions and analysis methods.
3. Estimate the benefits that would be derived from removing bottlenecks nationwide. Bottlenecks occur not only in the major metropolitan areas, but also in smaller ones.

O'Laughlin, R., D. Thomas, and R.M. Rinnan. Chicago Downtown Freight Study. In *TRB 87th Annual Meeting Compendium of Papers DVD.* Transportation Research Board of the National Academies, Washington, D.C. Nov 2007.

This report focused on urban freight delivery. The paper provides interviews and extensive field surveys to present the congestion problems and constraints and provides some solutions that have been effective. Many examples of improvements were described in this paper. Fifty recommendations were made and broken up into three categories:

- Use of public right-of-way
- New building designs and standards
- Addressing deficient building and roadway infrastructure.

Al-Deek, H., S. Ishak, and A.E. Radwan. The Potential Impact of Advanced Traveler Information Systems (ATIS) on Accident Rates in an Urban Transportation Network. *Proc. Fourth Vehicle Navigation and Information Systems International Conference (VNIS 93)*, Ottawa, Canada, 1993. pp. 634–636.

This paper describes how Advanced Traveler Information Systems (ATIS) has the potential to improve and enhance the transportation system performance. This paper reveals that the congestion-accident relationship is critical to the safety evaluation of traffic diversion with the ATIS.

Government Accountability Office. Highway Congestion: Intelligent Transportation Systems Promise for Managing Congestion Falls Short, and DOT Could Better Facilitate Their Strategic Use. GAO-05-943. Government Accountability Office Washington, D.C. Sep 2005.

This report describes in detail the positive effects of ITS technology and the Federal role in deployment of the ITS infrastructure. Four case studies have been described portraying the type of ITS technology being used. Studies show that ITS technology can mitigate congestion, and also lead to other benefits such as improved safety and reduced emissions harmful to the environment, when ITS is implemented properly.

Facanha, C. and J. Ang-Olson. Comparison of Technological and Operational Strategies to Reduce Trucking Emissions in Southern California. In *Transportation Research Record 1981.* Transportation Research Board of the National Academies, Washington, D.C. 2008, pp. 89–96.

This report's main focal point is achieving emission reductions from trucks. Major plans for development of more efficient movement of cargo and environmental safety are being developed by Southern California Association of Governments (SCAG) and other agencies. SCAG also developed technological and operational strategies and environmental programs for future improvement in truck emissions. This report also contains truck strategies that are evaluated and analyzed. Two operational strategies are also mentioned in this report, a virtual container jar and expanded incident management. Strategies discussed in this report are evaluated both in terms of emission reduction potential and cost effectiveness.

Federal Highway Administration. *Financing Freight Improvements.* U.S. Department of Transportation. Washington, D.C. 2007.

This report provides 51 case studies of financing strategies used for different types of freight-related projects. They are categorized by state. Many case studies mentioned in this report could be categorized as low-cost improvements.

Shafran, I. and A. Strauss-Weider. *NCHRP Report 497: Financing and Improving Land Access to U.S. Intermodal Cargo Hubs.* Transportation Research Board of the National Academies, Washington, D.C. 2003.

This report presents 12 projects/case studies and direction on the most effective strategies for financing improvements to cargo hubs and intermodal freight facilities. The report then identifies the best practices for financing options. Several of the projects may qualify as low-cost operational and capital improvements.

Rail

Bryan, J.G.B., G. Weisbrod, and C.D. Martland. Rail Freight as a Means of Reducing Roadway Congestion: Feasibility Considerations for Transportation Planning, In *Transportation Research Record 2008*. Transportation Research Board of the National Academies, Washington, D.C. 2007, pp. 75–83.

This paper provides a summary for NCHRP Project 8-42, which examined the feasibility and value of rail freight solutions as a means of reducing highway congestion. Some rail freight strategies for mitigating traffic congestion growth were defined and consist of rail freight enhancements and promotion of greater use of rail. This paper also provides case studies for various rail projects. All of the projects described were captured by four categories: enhancement of rail freight capacity and service for intercity corridors, enhancement of rail capacity and service along urban corridors, plans to enhance throughput and capacity of regional rail freight system, and enhancement of rail freight options for service to ports/terminals. This report also discusses the economic and institutional factors affecting feasibility of diverting some truck freight to rail.

Sun, Y., M.A. Turnquist, and L.K. Nozick. Estimating Freight Transportation System Capacity, Flexibility and Degraded-Condition Performance. In *Transportation Research Record 1966*. Transportation Research Board of the National Academies, Washington, D.C. 2006, pp. 80–87.

This report describes enhancements to an existing model of freight system capacity. The three enhancements expounded upon are (i) allowing future traffic patterns to be uncertain, (ii) replacing the simple facility capacity constraints by volume-delay curves and a service quality constraint, and (iii) replacing the predefined paths by traffic assignment logic so that link and path volumes are determined in the optimization without requiring path enumeration. These enhancements allow easy assessment of the performance of a freight network under conditions where individual links and/or terminals have degraded capacity. This will provide improved estimates of capacity and capacity flexibility.

Dirnberger, J.R. and C.P. Barkan. Lean Railroading for Improving Railroad Classification Terminal Performance Bottleneck Management Methods. In *Transportation Research Record 1995*. Transportation Research Board of the National Academies, Washington, D.C. 2007, pp. 52–61.

This paper defines "Lean Railroading" with emphasis placed on the bottleneck management component. "Lean Railroading" is an approach that adapts proven production management techniques to the railroad environment and can be used to guide improvement initiatives. Improved sorting processes and increased pull-down performance has potential to increase capacity without major capital, equipment or labor expense. Dirnberger describes the development of a quality of sort metric to reduce the occurrence of dirty tracks and measure adherence to a static track allocation plan if one is in place to help better manage interaction between the hump and the pull-down processes. This paper presents the Lean Railroading approach and discussed the bottleneck management component. Increasing pull-down capacity will help enable railroads to swap the time buffer for a capacity buffer. This will reduce dwell time leading to improved service reliability and network efficiency.

Lai, Y., O. Ouyang, C.B. Barkan, and H. Onal. Optimizing the Aerodynamic Efficiency of Intermodal Freight Trains with Rolling Horizon Operations, 2007.

This paper first develops a static model to optimize load placement on a sequence of intermodal trains that have scheduled departure times. This model applies when full information on all trains and loads is available. The purpose of this paper is to extend a loading model to optimize the aerodynamic efficiency at the multiple train system level. This paper also describes the development of a rolling horizon scheme for continuous terminal operations. They use a rolling horizon scheme to balance the advantage from optimizing multiple trains together, and the risk of making suboptimal decisions due to incomplete future information. This study focuses on intermodal services of the BNSF Railway between Chicago and Los Angeles. An empirical case study is also included showing significant aerodynamic efficiency benefits from these optimization models. Attempting to optimize the loading of too many trains in this environment will reduce the ability to achieve the most efficient loading configuration because of imperfect information.

Armstrong, J.H. *The Railroad: What It Is, What It Does*, 5th ed. Simmons-Boardman Books, Inc., Omaha, NE. 2008.

This book presents factual information on the basic technologies used by railroads and the operational functions they perform. A brief chapter is dedicated to each main topic, for example: locomotives, freight cars, signals & communications, terminal operations, intermodal traffic, and so on. Many carefully drawn and helpful illustrations supplement the text.

Association of American Railroads. *Railroad Facts*. Annual Editions, Policy and Economics Department, Washington D.C.

The railroad industry's trade association annually produces an indispensible collection of data on railroad scope, operations, financial performance, investments, traffic mix, safety trends, and employment. The statistics are provided for the industry as a whole (usually for Class I railroads only), and for the largest firms individually. Some key information is shown in graphical form, while other items are presented as historical series in tables.

Burns, J.B. *Railroad Mergers and the Language of Unification*, Quorum Books. Westport, CT. 1998.

Burns has written a useful and generally accurate history of railroad merger activity in the Twentieth Century and in his conclusions has attempted to put rail mergers in the larger context of business combinations and globalization at the turn of the 21st Century. His theme is that "merger was the common language of growing enterprises" (p. 175). The book has a good index and an excellent bibliography.

Cambridge Systematics Inc. *National Rail Freight Infrastructure Capacity and Investment Study*. Prepared for American Association of Railroads, Washington, D.C. Sep. 2007.

This report, undertaken at the request of the National Surface Transportation Policy and Revenue Study Commission, examined long-term capacity expansion needs for the railroad industry. By projecting both likely capacity expansion investments and anticipated traffic growth on maps of the U.S. rail network, Cambridge Systematics Inc. was able to highlight its forecast of congestion bottlenecks quite dramatically. The report also provides calculations of the capital requirements estimated to be necessary to overcome capacity bottlenecks and accommodate freight demand in 2035—an estimated total of some $148 billion in 2007 dollars.

Conant, M. Railroad Bankruptcies and Mergers, From Chicago West 1975–2001: Financial Analysis and Regulatory Critique. Elsevier, Oxford, UK. 2004.

Michael Conant's recent book on rail mergers in the last quarter of the 20th Century follows up on his earlier text, called *Railroad Mergers and Abandonments* (1964). The earlier book sought to establish both "the myth of interrailroad competition" and the existence of significant excess capacity (by a factor of over three—p. 11) in the industry, but the recent volume has a much narrower focus. In an introductory chapter, Conant makes a general case that economic regulation has led to resource misallocation, and he describes what has been accomplished in the way of reform. Two chapters address the Rock Island and Milwaukee bankruptcies, which have received little scholarly attention. Chapters describing mergers involving the Illinois Central, Union Pacific, and the Burlington Northern-Santa Fe round out this study.

DeBoer, D.J. and L.H. Kaufman. *An American Transportation Story, the Obstacles, the Challenges, the Promise*. The Intermodal Association of North America, Greenbelt, MD. 2002.

This book covers the major modes of transport: highways, ports and waterways, railroads, and airways. Kaufman is a journalist of long standing in the industry, and DeBoer is a former Federal civil servant and industry practitioner best known in the intermodal (truck-rail) industry. Each chapter provides an historical synopsis and current profile, while the final chapter addresses the challenges of future capacity constraints and solutions.

Friedlaender, A.F. *The Dilemma of Freight Transport Regulation*. The Brookings Institution, Washington, D.C. 1969.

This volume is a "background paper" for a Brookings conference of experts just before the time of the transport industry's greatest peril. The book summarizes the experts' discussion—much consensus on the need for policy changes, but little agreement on what those should be and how they could be achieved. It took the costly Northeast Rail crisis to begin changing legislative perspectives—including the notion that sacrosanct economic regulatory and competitive notions would have to be compromised.

Gallamore, R.E. "Regulation and Innovation: Lessons from the American Railroad Industry" in José Gómez-Ibáñez et al., *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer*. Brookings Institution Press, Washington, D.C. 1999. pp. 493–529.

This easily accessible "handbook" contains a collection of some of the best examples of work done on transportation economics. The piece by Gallamore tells how reform of regulation in the Staggers Rail Act of 1980 was critical in reversing the financial fortunes of railroads—and how the industry, using the cash flow dividends resulting from deregulation, was able to invest in new plant and equipment that embodied remarkably improved technologies—thus perpetuating and expanding the railroad "Renaissance" of the last two decades (1979–1999).

Healy, K.T. *Performance of the U.S. Railroads Since World War II: A Quarter Century of Private Operation*. Vantage Press, New York, NY. 1985.

This book is really two volumes in one: the first ten chapters describe the organization of the industry, provide historical perspectives on passenger and express services, give the fundamentals of pricing carload and less-than-carload services, and discuss labor and management issues; it is a more sophisticated and less mechanical version of Armstrong's resource manual. The remainder of the book details growth of the railroads by internal economic growth and acquisition since World War II. This material describes the setting and performance of a half century of railroad mergers. The book includes simple maps of some of the mergers he studied, and these have the virtue of showing merger partners in relationship to one another—as *parallel* acquisitions reducing competition or as *end-to-end* market extensions.

Kahn, A.E. ***The Economics of Regulation: Principles and Institutions, Volumes I and II,*** **The MIT Press, Cambridge, MA. 1988.**

It is perhaps the most comprehensive treatment of the economics of regulation and the institutions which grew up around it. Volume I covers the principles developed in classical public utility regulatory theory. It treats in depth issues of marginal cost pricing (short run and long run), price discrimination, economies of scale, and rate making under competition. Volume II turns to institutional issues such as protectionism, public utility performance, "natural monopoly," and destructive competition. In addition to railroad regulation, Kahn deals with natural gas transmission, trucking, and telecommunications regulatory issues.

Keeler, T.E. ***Railroads, Freight, and Public Policy*****. Brookings Institute, Washington, D.C. 1983.**

This book was written just after the awful decade of the 1970s, but before the Staggers Rail Act reforms had made their impact on railroad fortunes. The book gives an excellent discussion of economic fundamentals within the regulatory paradigm, and anticipates many of the post-Staggers policy issues such as Ramsey (or inverse elasticity) differential pricing. Appendices survey the economic literature on railroad scale economies and the so-called "natural monopoly" model, which Keeler helped popularize.

Klein, M. ***Unfinished Business: The Railroad in American Life*****, The University Press of New England, Hanover, NH. 1994.**

This is a history by way of a memoir built from Klein's earlier work on railroads, particularly his massive two-volume history of the Union Pacific. He profiles both Jay Gould (to most, a villain) and Edward H. Harriman (to almost everyone but Theodore Roosevelt, James J. Hill, and J.P. Morgan, a hero). Klein provides a brief case study of the most important technology accomplishment for railroads in mid-20th century America, dieselization. He also briefly addresses the streamliner era and prospects for high-speed passenger corridors.

Martin, A. ***Enterprise Denied: Origins of the Decline of American Railroads*****, 1897–1917. Columbia University Press, New York, NY. 1971.**

This is one of the finest books available treating the history of railroads in the modern era. Martin skillfully describes the background and content of the early railroad regulatory enactments—those in 1887, 1903, 1906, 1910, 1913, and the Federal takeover of railroads in 1917-1918. He tells how the "archaic Progressives" (including Presidents Teddy Roosevelt and William Howard Taft, Senators Robert La Follette and Albert Cummins, and future Supreme Court Justice Louis Brandeis) used regulation to stifle railroads at the very time they might have been evolving with important technologies and investments—to compete with the new surface transport mode powered by internal combustion engines and with vehicles operating over hard-surfaced public roads.

Meyer, J.R., J.P. Merton, J. Stenason, and C. Zwick, ***The Economics of Competition in the Transportation Industries*****. Harvard University Press, Cambridge, MA. 1959.**

This book blazed the trail for modern academic quantitative studies of transportation performance and policy—for railways, highway construction, motor carriers, pipelines, intermodal truck-rail, and domestic airlines. MPS&Z, as transportation students call it, changed the paradigm for transportation studies, which previously had been mainly descriptive texts profiling modes and institutions in the industry, or narratives of regulatory legislation and case law. The work was among the first (if not the first) to describe long-run multivariate statistical cost functions, and to develop statistical regressions for transport costing. In a sharp critique, MPS&Z illustrated how these "true" cost functions contrasted with expressions of conventional average cost accounting systems that relied on arbitrary allocation of overhead and common costs.

Middleton, W.D., G.M. Smerk, and R.L. Diehl. ***Encyclopedia of North American Railroads*****. University Press, Bloomington, IN. 2007.**

The Indiana group has produced a truly encyclopedic work—testimony to both the complexity of the railroad industry and the industry of dozens of railroad writers who contributed articles for the work. Five overview essays set the stage: Keith Bryant on development of the industry, H. Roger Grant on its social history, John H. White Jr. on technology and operating practices in the 19th Century, William Middleton on technology and operating practices in the 20th Century, and journalist Don Phillips on post-war developments and controversies that closed out the century. Then the *Encyclopedia* starts in with Accidents and plows on through to a biographical sketch of Robert R. Young, who as an official of the C&O and Nickel Plate railroads famously published an advertisement declaring "A hog can cross America without changing trains—but YOU can't."

Middleton contributes Appendix A that is a statistical abstract of the industry, with many tables and charts. Appendix B has railroad carrier and regional maps. Appendix C is a comprehensive glossary of railroad terms, and Appendix D lists the "130 most Notable Railroad Books" compiled by the editors of *Railroad History*. It is a good list but incomplete and uneven in coverage. Finally, Middleton, Smerk and Diehl provide an index to help guide readers to articles that may not be easily found in the *Encyclopedia's* alphabetical arrangement.

Saunders, R., Jr. *Main Lines: Rebirth of the North American Railroads, 1970–2002*. Northern Illinois University Press, DeKalb, IL. 2003.

Main Lines is the third of three books by Richard Saunders dealing with railroads in the 20th Century. The first, *Railroad Mergers and the Coming of Conrail* dealt especially with the Penn Central fiasco and start-up of Conrail. Saunders admits that it was soon "badly dated," as "[a]gainst all odds, Conrail had been a success." Saunders then went back to revise the first book heavily—publishing *Merging Lines: The American Railroads, 1900–1970* in 2001. The third volume is *Main Lines,* which completes the story to the end of the century. This book is flawed and weakly sourced; Saunders does not have a good grasp of economics, which shows in the errors he makes in discussions of avoidable costs and elasticities. The book uses overstated and opinionated language, as in this passage: "the sale of Conrail had been so ham-handed and so fraught with ideological zealotry that it mortally wounded most hope for privatization in the near future" (p. 240). Secretary Dole's efforts to sell Conrail to Norfolk Southern in the mid-1980s were, perhaps, "ham-handed," but the initial public offering of Conrail only two years later (in 1987) was an unqualified success for the government and the company, as was soon demonstrated.

Stover, J.F. *American Railroads*, 2nd ed. University of Chicago Press, Chicago, IL. 1997.

This book is the most accessible broad history of the construction and development of American railroads over their nearly 200-year history. Stover shows the interrelationships of railroads with most other landmarks of American history, wars, westward expansion, national governance, regulation, and technology. A useful chronology lists important dates in the story from 1794 to 1995, and a *Suggested Reading* section provides brief annotations.

Stover, J.F. *The Routledge Historical Atlas of the American Railroads*, Routledge, New York, NY. 1999.

The book features color line maps detailing the evolution of rail networks and the make-up of current railroad companies. Like the superior color-coded pull-out maps showing various rail gauges at the beginning of the Civil War in George Rogers Taylor and Irene D. Neu, *The American Railroad Network, 1861–1890,* Cambridge: Harvard University Press (1956), *The Routledge Historical Atlas* map of rail lines as they existed in 1861 immediately conveys the substantial advantage held by the North over the South in the extent and interoperability of their different rail networks. Two maps show the Congressional land grants, both accurately as they were legislated and in the distorted fashion as they were depicted in school textbooks.

Stone, R.D. *The Interstate Commerce Commission and the Railroad Industry*, Praeger, New York, NY. 1991.

In late 2008, as a severe economic crisis in financial and credit markets is playing itself out in the midst of a national election, we are witness to arguments for and against regulation of the banking and securities industry. Enormous volatility in the stock market leads both experts and pundits to ask if there should be governmental restraints on short sales of stock; the credit crisis in home loans drives questions about re-regulation of banking practices such as bundling subprime mortgages and sales of derivatives. Richard Stone's book unwittingly provides background for the current regulatory debates by telling the story of railroad regulation and deregulation from 1887 (the Act to Regulate Commerce—the so-called ICC Act) through a succession of historical periods up to the Staggers Rail Act of 1980.

***Task Force on Railroad Productivity. Improving Railroad Productivity*. Final Report. The National Commission on Productivity and the Council of Economic Advisors. Washington, D.C. 1973.**

This "blue ribbon" task force surveyed the railroad crisis as it was unfolding in the 1970s and recommended policy reforms. Alexander Morton was executive director of the study and authored most of the text. *Improving Railroad Productivity* received almost no press attention at the time, but it was important in crystallizing a consensus in the academic community and among Washington insiders on the urgent need for regulatory reform to avoid total collapse and nationalization of the railroad industry. Meyer and Morton followed up on the Productivity Task Force Report with an important article for the Harvard Business School research series, *The U.S. Railroad Industry in the Post-World War II Period: A Profile* (Reprinted from *Explorations in Economic Research,* Vol. 2, No. 4, Fall 1975).

Federal Railroad Administration. *A Prospectus for Change in the Railroad Freight Industry*. U.S. Department of Transportation, Washington, D.C. 1978.

Passage of the *Railroad Reorganization and Regulatory Reform Act of 1976* (popularly known as the 4R Act) was something of a watershed for American railroads because for the first time in a century of regulatory history, it sought to *lessen* rather than *increase* regulatory constraints on railroads. The 4R Act, however, was a flawed and largely ineffective statute. It gave lip service to permitting flexible rates, adequate revenues, and more rapid regulatory determinations, but left in place the whole Interstate Commerce Commission (ICC) apparatus, which for a while (until the appointment of Darius Gaskins as Chairman) worked to thwart reform. The ICC's 4R Act determinations gave little relief to railroads in dealing with inflationary cost increases or gaining exemption from regulation where adequate competition existed.

One useful section of the 4R Act mandated DOT to study deferred maintenance in the railroad industry and offer recommendations for ways of reversing unfavorable trends. These tasks were delegated to the Federal Railroad Administration (FRA), which responded with a remarkable report. The *Prospectus for Change* calculated deferred maintenance at some $13–16 billion over the coming decade unless reforms were made in regulation. It went on to detail regulatory and other changes needed to keep the railroads solvent in the private sector. The FRA's *Prospectus for Change* should thus be remembered, along with the Meyer Task Force *Productivity Report,* as the intellectual underpinning and blueprint for the monumental Staggers Rail Act of 1980. Contrary to conventional "history," the Staggers Act did not emerge full blown from Congressional committees or lobbyists' position papers, but rather had its origins with unsung civil servants of the Federal Railroad Administration and Department of Transportation.

Weatherford, B.A., H.H. Willis, and D.S. Oritz. *The State of U.S. Railroads. A Review of Capacity and Performance Data*, RAND, Santa Monica, CA, 2008.

RAND has produced an exceptional analysis of the current railroad situation. Sponsored by UPS, the project appears to result from concerns as to whether the railroads will be able to expand efficient operations under the pressure of rapidly increasing future freight volumes. The study points out that capacity constraints encountered by Union Pacific in March and April 2004 affected its new expedited long-distance intermodal service. These problems caused UPS to cease its new service, whereupon UPS shifted some intermodal freight back to the highways. "This example illustrates two important themes. The first is that railroad capacity constraints—resulting from trains running at different speeds and limited track, cars and locomotives, and crews—may lead firms to shift freight among modes. The second theme is that these private decisions have public costs" (p. 6). RAND concludes that "if railroads underinvest in new road [railway track, bridges, and signals], rail market share will continue to fall and the number of trucks on the road [highways] will grow at an accelerating rate" (p. 29).

Wilner, F.N. *Railroad Mergers: History, Analysis, Insight*, Simmons-Boardman Books, Omaha, NE. 1997.

Wilner attempted a comprehensive study of railroad mergers from shortly after the beginnings of the industry in 1830 through partition of Conrail in 1999, dividing most of the book into eras: the period before 1950; 1950 to 1979; and the 1980s and 1990s. Six essays from respected industry observers help provide context for legal, international and investment issues, and speculation about future challenges. Wilner's text tables are useful for looking up filing dates and the like, but cannot be said to contribute much "Analysis" or "Insight." Standard maps of U.S. railroads reproduced from the Rand McNally 1939 *Railway Atlas* locate each road on the national network, but fail to show how merger partners might overlap or extend the resulting systems.

Wyckoff, D.D. *Railroad Management*. Lexington Books, Lexington, MA. 1976.

Daryl Wyckoff produced valuable studies of managerial tasks in the trucking and railroad industries. This book provides both historical context and organizational theory to describe the tasks of railroad managers. Topics include functional organization; centralization; responses in commercial, competitive, and regulatory environments; handling construction and maintenance functions; labor and substitution of capital for labor; local vs. long-haul operations; profit center organization; and causes of organizational stagnation.

Immel, E. and B. Burgel. *Rail Capacity in the I-5 Corridor*. Presented for the Standing Committee on Rail Transportation, San Diego, CA, Oct. 2004.

This research used simulation techniques to examine rail capacity issues on I-5 and access to the port of Oregon. The paper identified factors that impact rail capacity to include:

- Speed and length of trains
- Differing priorities
- Many types of facilities in the same areas.

The paper also identified measures of performance to include:

- Average speed
- Hours of delay
- Delay ratio.

Finally, the paper identified a number of potential improvement options to address the freight mobility constraints:

- Increase track speeds
- Expanded yard capacity
- Adding controlled siding at certain sections
- Install second main track at certain sections.

Dennis, S.M. Changes in Railroad Rates Since the Staggers Act. *Transportation Research Part E* 37. 2000, pp. 55–69.

This document describes factors that may have caused a huge rate reduction after the Staggers Act. The objective of this paper is to determine the relative importance of the various factors underlying the decline in railroad rates since the Staggers Act. Some factors contributing to the decline in railroad rates are an increasing percentage of bulk commodities, increased length of haul, and increased private ownership of equipment. To determine the relative importance of these factors, this paper uses a reduced form railroad rate equation. Some results from this study are that shippers saved approximately 28 billion dollars per year, length of haul increased, private ownership increased, and equipment cited by some shippers accounted for only about 2 percent of the reduction in railroad revenue per ton-mile since deregulation.

Deepwater Ports and Inland Waterways

Government Accountability Office. *Surface and Marine Transportation: Developing Strategies for Enhancing Mobility: A National Challenge.* GAO-02-775. Government Accountability Office, Washington, D.C. August 2002.

Over the next 10 years passenger and freight travel are expected to grow by a large margin; with the increase, the surface and maritime transportation systems face a number of challenges to ensure continued mobility. This report also provides important information about the increase of freight mobility. The amount of freight moved is expected to increase to 19.3 billion tons annually by 2010. It states that trucks move the majority of freight tonnage and are expected to continue moving the bulk of freight into the future; trucks remain the dominant mode in terms of tonnage. International freight is an increasingly important aspect of the U.S. economy and water is the dominant mode in terms of tonnage. This report lists the following challenges:

- Preventing congestion
- Accessibility
- Addressing transportation's negative effects on the environment and community.

Three key strategies mentioned in this report are:

1) Entire maritime and surface transportation systems should be the main focus.
2) Include usage of all tools to achieve desired mobility.
3) Provide more options for financing mobility improvements.

Maritime Administration (MARAD). *Report to Congress on the Performance of Ports and the Intermodal System.* U.S. Department of Transportation. Washington, D.C. June 2005.

This report provides an assessment of the conditions of commercial ports. These assessments include the performance of major components of the intermodal system. MARAD emphasizes the unexpected surge in cargo during a military deployment and how the freight transportation infrastructure is expected to handle it. Port capacity is one of many issues this report touches on. Agile port projects help increase capacity on the same waterfront acreage by using sprint trains to take intermodal cargo directly from the dockside and move it to an inland location. Recommendations have been provided to guide port transportation system policies for the future. These improvements consist mainly of regulatory and policy changes.

Pfiegal, R. and A. Back. Increasing Attractiveness of Inland Waterway Transport with E-Transport River Information Services. In *Transportation Research Record 1963.* Transportation Research Board of the National Academies, Washington, D.C. 2006, pp. 15–22.

Innovative information systems have a positive impact on freight mobility, affecting safety and efficiency. This paper describes a telematic service to support traffic and transport management called River Information Services (RIS). RIS will improve the information processes of inland navigation. The setup of RIS includes electronic navigation charts and vessel tracking and tracing systems (automatic identification systems). E-Transport applications make use of the RIS core system and provide advanced services, namely electronic ship reporting and collision avoidance. Austria is the first country to implement this new technology to provide a safer and more efficient mobility.

***Special Report 279: The Marine Transportation System and the Federal Role: Measuring Performance, Targeting Improvement.* Transportation Research Board of the National Academies, Washington D.C., 2004.**

This report identifies waterway infrastructure needs based on collected data, studies, and surveys provided by MARAD. The few issues and recommendations that stood out consisted of:

- Deeper and wider channels to accommodate more and larger ships;
- Modernized locks and dams to increase service reliability, capacity, and speed
- New information and navigation technologies to integrate the supply chain and security and safety systems; and
- More efficient use of land for marine terminal operations and environmental protection.

A number of concerns were repeated in this report including insufficient capacity; delays in the dredging of harbor channels; modernizations of locks; and absence of systematic and comprehensive efforts to strengthen marine safety, security, and environmental protection. The corresponding actions to these concerns are to have a more balanced set of tools to make national transportation investment and policy decisions that recognize the increasing integration of the transportation modes. Also collaborate with industries and Federal agencies to undertake an applied research and technology program aimed at furthering capacity, environmental protection, etc. Lastly the report expressed the need for developing a further understanding of the operations, capacity, and use of the system, and of freight systems in general.

Knatz, G. National Port Planning: A Different Perspective. In *Transportation Research Record 1963.* Transportation Research Board of the National Academies, Washington, D.C. 2006, pp. 52–55.

This paper addresses the implications of growth for the Ports of Long Beach and Los Angeles and how decisions made to address cargo growth there can have national repercussions. An analysis of statewide port capacity can guide port planning and provide a clear understanding of capacity issues. Identifying and prioritizing infrastructure improvements cannot be accurately done due to the lack of or failure to examine the port system as a whole. Four fundamental problems are identified:

- Congestion problems in urban areas surrounding the nation's largest ports have mobilized communities to seek locally imposed limits on port expansion.
- Port infrastructure requires a significant amount of time to plan and construct in today's environmental climate. These events need to be planned well in advance.
- Federal dredging projects are hampered by an obsolete funding formula for cost sharing that was developed on the basis of the vessel fleet of the early 1980s.
- The fundamental principles of coastal protection legislation are being questioned.

Le-Griffin, H.D. and M. Murphy. Container Terminal Productivity: Experiences at the Ports of Los Angeles and Long Beach. *Proc. National Urban Freight Conference*, Long Beach, CA.

This paper describes a study that examined the productivity of the Los Angeles and Long Beach ports and compares them with other major container ports in the U.S. and overseas. The paper noted that with the increasing demand for international trade and global logistic services, there is the need for substantial investments and improvements in physical capacity and operational efficiencies to enhance productivity of terminals. The paper identifies a range of internal and external factors that influence the productivity of container terminals. The external factors include the size and type of ships accommodated by the terminal as well as the landside capacities and performance of intermodal rail and highway systems serving the ports. The paper also identifies strategies to improve productivity:

- Reduced container dwell time—containers coming off ships first do not receive as much free time as before with the result that carriers have started removing those containers from the terminals sooner to avoid storage fees.
- Extended hours of operation—increasing the number of hours and shifts that terminal gates remain open
- Inland container yard—moving some containers to holding sites outside the terminal areas where there is more land available for storage.

Dekker, S., R.J. Verhaeghe, and A.A.J. Pols. Economic Impacts and Public Financing of Port Capacity Investments. In *Transportation Research Record 1820.* Transportation Research Board of the National Academies, Washington, D.C. 2003. pp. 55–61.

This report focuses on the public/private financing of port investments to improve efficiency and reduce congestion. Large-scale infrastructure is described as seaports and airports. This report emphasizes impacts of large-scale infrastructure projects; examples are costs due to congestion, air pollution, and noise. The Case of Rotterdam Port Area Expansion is also discussed in this report. The efficient or inefficient use of space determines the need. Because of low land prices in the Rotterdam port area, container transshipment is growing and involves higher distribution and storage requirements. This report includes a decision-making framework process for the Maasvlakte investment. The report identified these investments: investments to improve physical capacity of the port itself and investments to improve hinterland connections.

Klodzinski, J. and H.M. Al-Deek. Transferability of an Intermodal Freight Transportation Forecasting Model to Major Florida Seaports. In *Transportation Research Record 1820.* Transportation Research Board of the National Academies, Washington, D.C. 2003. pp. 36–45.

This paper focuses on the development of a transportation forecasting model to better predict future capacity issues. The report identifies operational improvements that need attention, which are accessibility for heavy trucks to access port terminals. Improvements to infrastructure of seaports transportation operations are discussed.

Soriguera, F., F. Robuste, R. Juanola, and A. Lopez-Pita. Optimization of Handling Equipment in the Container Terminal of the Port of Barcelona. In *Transportation Research Record 1963.* Transportation Research Board of the National Academies, Washington, D.C. 2006. pp. 22–51.

This paper analyzes the internal transport system in a marine container terminal and investigates the effect of the type of handling equipment used. Congestion at ports is caused not only by ship and wharf, but also by port activities. Using research from Port Planning and Development, the authors state that the transfer capacity between ship and wharf achieved by the wharf cranes exceeds the capacity of the port handling equipment to move, stack, and deliver the cargo. Therefore the capacity of the handling equipment between the wharf and the storage yard is critical. This paper describes the basic functions of a marine container terminal as loading, unloading, storage, reception, and delivery of containers through the gates.

Global Insight Inc. Port Tracker: Monthly Trade Logistics and Intermodal Outlook. National Rail Federation, Washington, D.C. 2007.

An econometric forecasting model for major U.S. ports was developed by Global Transportation Service. The data were collected from both public and private sources. Some of the highlights included in this newsletter are:

- The slowest traffic month of the year is Feb. 2007 and Vancouver is rated medium for congestion.
- All uncovered U.S. ports are operating without congestion from the harbor to gate.
- Rail performance has improved.
- Monthly container volumes are higher than last year's.

This document contains container volume highlights. U.S. ports are operating congestion free, while truck and rail performance is more than adequate for the slow season volume. They rate the West and East Coast ports according to their congestion.

Yonge, M. *European Union Short Sea Shipping: European Union Transport Initiatives to Achieve Sufficient Mobility in Order to Sustain Economic Growth*. Ft. Lauderdale, FL: Maritime Transport & Logistics Advisors. 2004.

Short sea shipping is seen as an opportunity to maintain, if not enhance, the European Union Flag Maritime transport sector as well as maritime employment of EU state members. The benefits of short sea shipping are that infrastructure costs are low unlike rail and highway and energy consumption is virtually insignificant and environmentally friendly. Water transport and rail modes are encouraged to keep up with the growth. This report suggests that the only way to keep up with the increasing demand is through short sea shipping. This report also describes EU's TEN-T (Priority Projects) that include short sea shipping, roadway, railway, inland waterway, airports, seaports, inland ports, and traffic management. These projects would:

- Produce significant time savings
- Reduce CO_2 emissions and other emissions
- Rebalance the modal split
- Stimulate intermodal trade
- Reduce road congestion
- Improve welfare.

Konings, R. "Ports of Long Beach and Los Angeles Transportation Study." In *Transportation Research Record 1820*, Transportation Research Board of the National Academies, Washington, D.C. 2003, pp. 26–35.

The article mainly focuses on the creation of the trip generation model used to study recommended improvements to the Ports of Long Beach and Los Angeles. Data were collected and assumptions were made about the truck and automobile traffic at and near the terminal. The distribution of trucks and automobiles over the network was developed by doing a driver survey at 13 container terminals during a 4-hour period. They also conducted traffic counts to separate the vehicles of those that reported to the union halls and then to the terminals, from those that reported directly to the terminals.

It references a developing system that could potentially be a low-cost, quickly implementable solution to ease freight congestion. It is an appointment system for container pickup. This system is within eModal, the Internet system that most of the container terminals and many harbor trucking companies use. In the trip generation estimates, they defined a changing operation parameter of increased street turns as a result of the use of the eModal system.

APPENDIX C

Interview Guide

Project: NCFRP 04: Identifying and Using Low-Cost and Quickly Implementable Ways to Address Freight-System Mobility Constraints

Purpose of Study and Interview Objectives

The primary objective of the study is to develop and test a methodology to successfully address multi-modal freight mobility congestion points through low-cost, quickly implementable physical and operational improvements. The purpose of the interviews is to gather sufficient information to develop a better understanding of constraints facing freight transportation by different modes and the range of improvements taken to remove these constraints. The interview guide is designed with the primary objective to obtain sufficient information on:

- Definition of freight mobility constraint
- Identification of constraint indicators and trigger factors
- Definition of low-cost and quickly implementable (quick fix) improvements
- Decision process/approach in selecting appropriate improvements
- Cost of low-cost improvements
- Examples of implemented improvements.

General

The purpose of this section is to gather information on the types of freight activities undertaken by the organization.

1. Name or interviewee, phone number, email, fax
2. Name of agency
3. What is your agency's major freight-related activity?
4. What roles does your agency play in
    - identifying mobility constraints or
    - monitoring freight mobility indicators or
    - implementing improvements or
    - evaluating effectiveness of improvements?
5. What other agencies does your agency collaborate with in assessing and addressing freight mobility issues?

Agencies Responsible for the Provision, Maintenance, and Regulation of Transportation Infrastructure (State DOTs, MPOs, Terminal Operators, Federal Agencies, etc.)

The questions in this section are directed at gathering information on identification and classification of mobility constraints as well as definition and selection of improvement options.

1. What are the predominant modes of freight transportation of your agency?
2. From your perspective, how would you define a "freight mobility constraint"?
3. What are the major causes of freight mobility constraints?
4. What are the major severe and persistent freight mobility constraints that you experience?
5. What are the indicators of the major freight mobility constraint (e.g., traffic volume, truck percentage, delay, level of service, service reliability)?
6. How would you characterize the various types of freight mobility constraints (e.g., physical capacity, operational, regulatory)?
7. Do safety regulations (FRA/FMCSA/RITA/MARAD) impose unwarranted burdens such as to impede mobility and efficient operations? If so, what reforms could be made that would ensure both safety and efficiency?
8. Do planning and environmental regulations (FHWA, STB, EPA, Corps of Engineers, State agencies) impose unwarranted burdens such as to impede mobility and efficient operations? If so, what reforms could be made

that would ensure both environmental protection and efficiency?

9. How do any Department of Homeland Security (and international) requirements interfere with efficient freight movements (highway, rail, ports, inland waterways, pipeline)?
10. Where do these constraints mostly occur in the freight transportation system—highway or rail class (interchanges, etc.)?
11. What steps are involved in selecting potential improvement options (decision process)?
12. What alternatives are considered in trying to address the freight constraints (by type)?
13. What factors are considered in selecting an improvement action (e.g., cost, implementation time, safety)?
14. How would you characterize a "low-cost" action directed at improving freight mobility?
15. How would you characterize a "quickly implementable" or "quick fix" improvement action directed at addressing freight mobility constraint?
16. Do you typically use benefit-cost analysis in selecting alternative options?
17. What is the role of stakeholders in selecting and implementation of improvements?
18. What are the measures and how do you assess the success of implemented improvements?
19. Please provide the following information on examples of implemented improvements by type of improvement
    a. type of improvement
    b. cost of improvement
    c. duration of improvement
    d. impacts of improvement action
20. What are potential sources of detailed information on implemented improvements?
21. Do you have any comments that you would like to add?

Rail—Additional Questions

1. Is any part of your railroad currently operating at full capacity? e.g.,
2. Where/what kind of congestion and bottlenecks are most severe and persistent?
    a. Yards and Industrial Switching Terminals
    b. Line Haul (include major maintenance windows/work performed under traffic)
    c. Intermodal Terminals
    d. Locomotive Power
    e. Crews
    f. Maintenance Shops
3. What are the causes of the most severe capacity problems? e.g.,
    a. General economic growth
    b. Secular growth in key commodities
    c. Cyclical boom/bust in imports/exports related to the strength of the dollar
    d. Economic/re-regulatory uncertainty causing us to be cautious about reinvestment
    e. Insufficient cash flow for re-investment, e.g., "not earning our cost of capital"
    f. Car supply shortages
    g. Other materials or construction supply shortages, e.g., steel rail, concrete, signal systems
    h. Other
4. Do you believe improving your service reliability "creates" capacity through improved asset utilization, or requires additional (surge) capacity to stay on schedule?
5. What technologies would help you improve service reliability?
    a. Train control/advanced dispatching
    b. Onboard sensors
    c. Rapid on/off maintenance of way machinery
    d. Electronically controlled pneumatic brakes
    e. Advanced electronic inspection techniques
    f. Trunked digital communications systems
    g. Other
6. Do you have any comments that you would like to add?

Short-Line and Regional Railroads

1. Are there impediments to freight mobility that short lines and regional railroads face that make re-acquisition by Class Is more or less likely? What are they, and which direction do they point?
2. How effective do you think short lines are in supporting participation by local industry in national rail service markets? Do they help overcome Class I bottlenecks/labor constraints/service weaknesses?
3. Is there a need for improved computerized management systems that are scaled to short-line operations and interoperable with the Class Is? If so, how might they be developed and deployed?
4. Do you have any comments that you would like to add?

Ports and Terminal Operators—Additional Questions

1. What are the top 3 issues you face regarding physical constraints to your port or terminal operations? e.g.,
    a. wharf conditions,
    b. terminal layout,
    c. gate configurations,
    d. barriers to rail efficiency,
    e. access to streets and highways outside the gate
    f. inside the gate operations?
2. What are the top 3 issues you face regarding operational constraints to your port or terminal operations? e.g.,

a. ship arrival time
b. sufficient labor
c. checking situation at gates
d. cargo movements within the terminal
e. ability to adjust to peak flow periods
f. gaps in technology

3. What are the top 3 issues you face regarding regulatory requirements (e.g., security, safety, and environmental concerns)? Are these causing delays in cargo throughput that need to be addressed?
4. To what extent do you use electronic identification systems and other technical tools to track containers, communicate with logistics providers, meet homeland security requirements, and participate in information sharing with local transportation agencies? Please give some examples where these applications have helped improve the flow of cargo and alleviated congestion problems.
5. Overall, how would you rate the "value" of your ability to quickly act, at relatively low cost, to address congestion problems at your port or on your terminal and in moving cargo on and off terminal?
6. Do you have any comments that you would like to add?

Freight Operators—Motor Carriers, Freight Forwarders, Logistics, Warehouse

The questions in this section are directed at gathering information on operators' perspectives of freight mobility constraints and impacts of improvements.

1. Are there areas of the country where you assess congestion/mobility-related accessorial charges?
2. From your perspective, how would you define a "freight mobility constraint"?
3. Are there areas of the country where you face mobility constraints more than other areas?
4. What mobility constraints do you face in these identified areas of the country?
5. What are the major causes of freight mobility constraints?
6. How would you characterize the various types of mobility constraints you face?
7. At what type or types of facilities do your drivers most frequently encounter freight mobility challenges (ports, rail yards, intermodal facilities, major bridges and tunnels, urban areas, etc.)?
8. Do safety regulations (FRA/FMCSA/RITA/MARAD) impose unwarranted burdens such as to impede mobility and efficient operations? If so, what reforms could be made that would ensure both safety and efficiency?
9. Which facilities offer better freight mobility than others? If so, what makes the difference?
10. What metrics does your fleet use to identify freight mobility challenges, either recurring or non-recurring?
11. How do you respond to each type of constraint?
12. What are the 3 most common operational impacts of freight mobility constraints? How do they affect your customers (shippers and consignees)?
13. Have freight mobility issues changed your operating practices? If so, how?
14. What improvements have improved mobility and which have not?
15. Outside of major infrastructure improvements, are there short-term fixes (facility-based, operational, etc.) to freight mobility issues that you would judge as successful? Are there others that you might propose?
16. Of those short-term fixes, are there thresholds that you would use to define "low-cost" and "quickly implementable?"
17. Do you have any comments that you would like to add?

Labor Unions

Labor and their union organizations negotiate collective bargaining agreements that specify terms and conditions for their work efforts, including ways to improve safety, decrease lost time, and educate members to accomplish jobs using new technologies. Both management and labor ascribe to these goals. How labor cooperates and supports low-cost and quickly implementable actions will vary by mode and function within that labor group's sphere of influence. The following questions are generic and may be modified by mode and labor participant in the interview process.

1. From your perspective, how would you define a "freight mobility constraint?"
2. What are the top 3 issues or problems you face in your work that impact freight flow and involve congestion? In this case, congestion is defined as a delay or blockage in the supply chain that causes a "back-up" to freight flow.
3. What are the top 3 actions you have seen implemented that have helped reduce these congestion problems if at all and, if not, what would you suggest could be done to address them?
4. How do you know when things are operating smoothly during your work day and when they are not, what causes the most delays and barriers to doing so?
5. Has your union been able to work with management to try to implement what might be considered "best practices" in supplying labor when needed? For example, do you sit down with management on a regular basis to determine when labor will be needed so that workers will be ready to go as soon as the freight needs to be moved? Are there

other cooperative examples you can cite where specific problems affecting the speed of freight flow have been addressed by your workers?

6. What would you consider to be a "low-cost" or "quickly implementable" fix to address congestion issues? Can you give an example of one that has worked including cost and time it took to implement?
7. Can you make decisions about problem solving improvements at your level of decision making or do you have to go through a process for approval by persons higher up in the organization? Can you give an example of one such improvement including the time and cost to you of sending it up the chain of command for approval?
8. How do you measure the flow of cargo involving your labor to move cargo?
9. To what extent do you use electronic identification systems and other technical tools to track containers, communicate with logistics providers, meet homeland security requirements, and participate in information sharing with local transportation agencies and other unions? Please give some examples where these applications have helped improve the flow of cargo and alleviated congestion problems.
10. To what extent are international and homeland security requirements adding to operational constraints for you in transporting freight?
11. Overall, how would you rate the "value" of your ability to quickly act, at relatively low cost, to address congestion problems in carrying out your work efforts to move freight?
12. Do you have any comments that you would like to add?

APPENDIX D

Internet Survey Instrument

The National Cooperative Freight Research Program through the Transportation Research Board (TRB) is conducting research to identify freight mobility constraints and develop a methodology to deploy tested, low-cost, quickly implementable physical, operational, and regulatory improvements that address such constraints. This survey is intended to help gather information on how you define freight mobility constraints and actions you take to address them or react to such constraints. This survey is organized in two sections:

- **Section I - General Freight Mobility Information** (Questions 1- 13).

  Please answer all of the questions in this section. In addition answer all questions in Section II that are specific to your modal operations, as follows. We appreciate your time and input in completing this survey.

- **Section II - Freight Mobility Modal Specific Information**
  - Motor carriers—Questions 14–21
  - Port terminal operators, port authorities—Questions 22–27
  - Railroads—Questions 28–32
  - Shippers, freight forwarders, logistics service providers, warehouse operators, labor unions—Questions 33–36
  - State DOTs, MPOs, Federal agencies—Questions 14–36

Section I—General Freight Mobility Information

Please answer all the questions in this section

1) Which **one** of the following best describes your organization? (Select one)

- State Department of Transportation ❑
- Metropolitan Planning Organization ❑
- Federal Agency ❑
- Air Freight Carrier ❑
- Motor Carrier ❑
- Short-Line Railroad ❑
- Class I Railroad ❑
- Deepwater Port Terminal Operator ❑
- Inland Waterway Operator ❑
- Port Authority ❑
- Freight Forwarder ❑
- Logistics Services Provider ❑
- Warehouse Owner/Operator ❑
- Shipper ❑
- Labor Union ❑
- Supplier ❑

2) Which **one** of the following best describes the predominant mode of freight movement that you are responsible for? (Select one)

- Trucks/Highway ❑
- Rail ❑
- Water/Ports ❑
- Air ❑
- Pipeline ❑

3) How would you define "freight mobility constraint"?

____
____
____

4) Which **five** of the following **performance indicators** do you most often use to monitor freight mobility systems and identify major constraints? (Rank 1 through 5; with 1 being the highest).

- Average speed ____________
- Delay ____________
- Stops per hour ____________
- Idle time ____________
- Level of service ____________
- Traffic volume ____________
- Truck percentage ____________
- Driver utilization/mile ____________
- Dwell time in hours or days ____________
- On-time arrival and/or departure ____________
- On-time customer pickup and/or delivery ____________
- Lifts per hour or shift ____________
- Gate transactions per day ____________
- Truck trips per day ____________
- Other (specify) ______________________

5) Which **five** of the following do you consider to be the **major causes of freight mobility constraints** for your operations? (Rank 1 through 5; with 1 being the highest).

- Inadequate physical capacity ____________
- Highway geometry ____________
- Inadequate system management ____________
- Regulatory constraints ____________
- Land use controls and regulations ____________
- Insufficient funding ____________
- Inadequate internal and external communications ____________
- Uncertain permitting outcomes ____________
- Insufficient trained labor ____________
- Inadequate attention to safety ____________
- Grade crossings ____________
- Other (specify) ______________________________

6) How would you **characterize the major freight mobility constraints** affecting your operations? (Rank 1 through 5; with 1 being the highest).

- Physical capacity ____________
- Operational limitations ____________
- Regulatory restrictions ____________
- Technological limitations/inadequacy ____________
- Financial limitations ____________

7) How much do Department of Homeland Security (and international) requirements (e.g., C-TPAT, SFI, 100% scanning 10+2 program) interfere with efficient freight movements? (Select one)

- None ❑
- Not much ❑
- Somewhat ❑
- Very much ❑

8) In your opinion, to what extent do Federal and state **safety regulations** impede mobility or improve efficient operations? (Select one)

- Impede very much ❑
- Impede somewhat ❑
- No impact ❑
- Improve somewhat ❑
- Improve very much ❑

9) In your opinion, to what extent do Federal, state, and local **land use and environmental regulations** impede mobility or improve efficient operations? (Select one)

- Impede very much ❑
- Impede somewhat ❑
- No impact ❑
- Improve somewhat ❑
- Improve very much ❑

10) To what extent do you consider the following factors when evaluating an improvement action?

Factors Used to Evaluate Whether or Not to Implement an Improvement Action	**Never used**	**Not often used**	**Often used**	**Always used**
Cost				
Benefits (perceived and actual)				
Funding availability/source				
Implementation time				
Safety				
Security				
Risk				
Regulatory requirements				
Other (specify)______________________				

11) To what extent do you implement the following steps when selecting potential improvement options?

Steps in Selecting Potential Improvement Options	**Never used**	**Not often used**	**Often used**	**Always used**
Benefit-Cost analysis				
Historical information (past performance)				
Stakeholder /customer input				
Other (specify) _____________				

12) How would you characterize a "**quickly implementable" or "quick fix**" improvement action directed at addressing freight mobility constraints? (Select one)

- Less than 6 months ❑
- At least 6 months but less than 1 year ❑
- At least 1 year but less than 2 years ❑
- At least 2 years ❑

13) How do you **assess the success** of implemented improvements? (Select all that apply)
- Before and after studies ❑
- Benefit-cost analysis ❑
- Customer feedback ❑
- Key performance indicator analysis ❑
- Other (specify) ______________________ ❑
- None ❑

Section II - Freight Mobility Modal Specific Information

Motor Carriers - please answer Questions 14 to 21

14) What is your primary type of operation? (Check all that apply.)
- For-Hire ❑
- Truckload ❑
- Less Than Truckload ❑
- Specialized (flatbed, tanker, bulk) ❑
- Private Fleet ❑
- Intermodal (port or rail) ❑
- Third party logistics provider ❑
- Other (please specify):________________________ ❑

15) What type of operation best describes your company? (Select One)
- Regional ❑
- National ❑
- International ❑

16) How often do the following **physical constraints** occur in your operations?

Physical Constraint	Never	Not often	Often	Very often
Major interchanges				
Bridges and tunnels				
Intermodal connectors				
Steep grades				
Port terminals				
Intersections				
Rail yard and switching				
Toll facilities				
Local road access				
Other (specify) _________________				

17) How often do you encounter the following **regulatory constraints** in your trucking operations?

Regulatory Constraint	Never	Not often	Often	Very often
Hazmat regulations and route restrictions				
Hours of service				
Differences in truck size and weight limit regulations				
Speed limit differentials				
Other (specify) _________________				

18) How often do you encounter the following **operational/technological constraints** in your trucking operations?

Operational/Technological Constraint	Never	Not often	Often	Very often
Parking restrictions/inadequate parking				
Truck lane restrictions				
Traffic signal timing				
Inadequate warning signs				
Other (specify) _________________				

19) How often do the following consequences occur due to mobility constraints?

Operational Area	Never	Not often	Often	Very often
Increased operating costs				
Decreased levels of service				
Loss of business				
Longer transit time				
Driver recruitment/retention				
Increased safety risks				
Other (specify) _________________				

20) How often do you take the following actions to respond to physical, operational, technological or regulatory freight mobility constraints?

Strategy	Never	Not often	Often	Very often
Reschedule trip/delivery				
Use third parties/agents				
Add equipment/drivers/resources				
Seek regulatory changes				
Use alternate routes				
Deploy in-cab communication				
Other (specify) _________________				

21) To what degree do the following low-cost improvements help improve freight mobility?

Improvement Action	No impact	Marginal improvement	Significant improvement
Auxiliary lanes			
Paved shoulders			
Acceleration and deceleration lanes			
Re-striping to add more lanes			
Ramp metering			
Ramp widening			
Temporary ramp closure			
Traveler information			
Truck restrictions			
Truck climbing lanes			
Traffic signal synchronization			
Intersection turn lanes			
Improved intersection turn radius			
Removal of vertical clearance impediments			
Other (specify) ________________			

Deepwater Port Terminal Operators; Inland Waterway Terminal and Carrier Operators; Port Authorities - please answer Questions 22 to 27

22) How often do you encounter the following **physical constraints** in your terminal, waterway, or port operations?

Physical Constraint	Never	Not often	Often	Very often
Dangerous wharf conditions				
Inadequate waterway or channel depths				
Inefficient terminal layout				
Inadequate terminal capacity				
Empty container storage and movement				
Restrictive gate configurations				
Inadequate security and government agency inspection areas				
Lack of maintenance shop capacity and dedicated area				
Inadequate chassis storage areas				
Insufficient on-dock rail				
Physical barriers to rail operations				
Inadequate local street and highway access from terminal				
Other (specify) ________________				

23) How often do you encounter the following **operational constraints** in your terminal, waterway, or port operations?

Operational Constraint	Never	Not often	Often	Very often
Late ship or tug arrival time				
Insufficient labor as ordered and needed				
Insufficient supply of trained labor				
Unclear traffic directions within the terminal for trucks and yard equipment				
Internal communication difficulties up and down the chain of command				
External communication difficulties across modes				
Inadequate planning for handling unexpected disruption				
Inability to ramp up for peak periods. Differences in communications and software programs among supply chain partners and customers. Excess on-terminal dwell time.				
Transportation Worker Identification Credential (TWIC) requirements				
Unplanned requirements and costs related to air quality and environmental factors				
Proprietary information barriers to modal coordination				
Compliance with international operational requirements				
Other (specify) ________________				

24) How often do you take the following actions to respond to physical, operational, and regulatory freight mobility constraints?

Actions to Respond to Physical, Operational, and Regulatory Constraints	Never used	Not often used	Often used	Always used
Empower problem solving action groups				
Prepare contingency plans				
Budget for implementing contingency plans				
Expand gate capacity				
Expand gate operation hours				
Adopt program to encourage off-peak terminal operations				
Upgrade communication technologies				
Support labor training programs				
Establish labor/management operations planning and trouble-shooting teams				
Institute risk reducing contract terms with customers and modal partners				
Coordinate capital improvement planning and improvements with modal and community partners to avoid unanticipated negative congestion consequences				
Regularly communicate with elected officials, management, and community stakeholders to garner support for regulatory improvements				
Use customized technology programs				
Other (specify) ________________				

25) What are the **five** most common operational impacts of freight mobility constraints? (Rank 1 through 5; with 1 being the highest).

Delay ____________
Increased operating cost ____________
Loss of business ____________
Loss of employees (drivers) ____________
Environmental impacts ____________
Other (specify) ____________________________

26) To what extent do you believe the following low-cost improvements help address/eliminate freight mobility constraints?

Low-Cost Methods to Address Freight Mobility Constraints	No potential	Low potential	Some potential	High potential
Auxiliary gate lanes				
Paved holding areas outside the gate				
"Fast Lane" at gates using paperless checking				
Terminal reconfiguration to add more capacity				
Truck reservation system				
Establish regular pre-planning meetings to coordinate ship, rail, labor, drayage requirements				
On-terminal traffic management by managers				
Locate secured inspection areas outside of major traffic areas				
Dedicated truck lanes on local roads outside the gate				
Synchronize signals at terminal entrance/exit to adjust to peak traffic hours on local roads and at terminal				
Utilize wireless communications on terminal to facilitate proper storage, ship operations, and gate operations				
Other (specify) ________________				

27) Please provide any explanatory comments to the above responses or additional information on freight mobility constraints.

____
____

Section II
Railroads - please answer Questions 28 to 32

28) Which are the **five** most severe and persistent **freight mobility constraints**? (Rank 1 through 5; with 1 being the highest).

Constraint	
Yard capacity	
Switching efficiency	
Lack of double or triple tracking	
Lack of sidings	
Intermodal terminals	
Locomotive power and freight cars	
Crews (labor availability)	
Maintenance shops	
Vertical double stack restrictions	
Signaling restrictions or lack of optimized signaling	
Speed restrictions in urban areas	
Other (specify) ________________	
Other (specify) ________________	

29) Which **five** capacity problems are the **major causes** of freight mobility constraints? (Rank 1 through 5; with 1 being the highest).

Capacity Problem	
General economic growth	
Cyclical growth in key commodities	
Cyclical boom	
Economic/re-regulatory uncertainty	
Insufficient cash flow for re-investment	
Car supply shortages	
Other materials or construction supply shortages, e.g., steel rail, concrete, signal systems	
Competition from other modes	
Environmental regulations	
Other (specify) ________________	

30) How often do you take the following actions to respond to physical, operational, and regulatory freight mobility constraints?

Actions to Respond to Physical, Operational, and Regulatory Constraints	Never used	Not often used	Often used	Always used
Reschedule trip/delivery				
Use alternative routes				
Use third parties				
Pass on delay costs to customers				
Deploy in-cab communication				
Seek regulatory changes				
Upgrade communication technologies				
Support labor training programs				
Establish labor/management operations planning and trouble-shooting teams				
Other (specify) ________________				

31) To what degree do the following low-cost improvements help improve freight mobility?

Low-Cost Action	No impact	Marginal improvement	Significant improvement
Technologies			
Train control/advanced dispatching			
On-board sensors			
Rapid on/off maintenance of way machinery			
Electronically controlled pneumatic brakes			
Advanced electronic inspection techniques			
Trunked digital communications systems			
Other (specify) ________________			

32) Please provide any explanatory comments to the above responses or additional information on freight mobility constraints.

____
____
____

Section II—Freight Forwarders, Shippers, Labor Unions, Suppliers - please answer Questions 33 to 36

33) How often do you encounter the following freight **mobility constraints** in your operations?

Constraint	Never	Not often	Often	Very often
Labor contract/agreement issues—FELA liability if any				
Insufficient supply of trained labor—restrictions on contracting out				
Safety concerns				
Insufficient storage capacity				
Availability of technology tools—e.g., for tracking and tracing inadequacies				
Delays or higher costs due to regulatory restrictions				
Communication among stakeholders				
Inadequate planning for handling unexpected demands and/or recovery from unplanned events				
Late arrival of shipments, especially if tardy arrival required more costly substitute transportation				
Unreliable shipment schedules—spot or chronic				
Safety of shipments—damage to lading				
Security of shipments				
Other (specify) ________________				

34) How often do you take the following actions to respond to freight mobility constraints?

Actions to Respond to Constraints	Never used	Not often used	Often used	Always used
Reschedule trip/delivery				
Increase number of trips				
Reroute delivery				
Use third parties/agents				
Add equipment/ resources				
Pass on delay costs to customers				
Seek constructive damages under a contract or legal judgment				
Seek regulatory changes				
Revise operating schedules				
Prepare and implement contingency plans				
Expand warehouse storage capacity or house tracks				
Resolve labor-related issues				
Adopt schedules consistent with both regulatory requirements and business imperatives				
Upgrade communication technologies, wired or wireless				
Support carrier-sponsored labor training programs				
Establish labor/management operations planning and trouble-shooting teams—for "corrective action"				
Other (specify) ________________				

35) What are the **five** most important impacts of freight mobility constraints? (Rank 1 through 5; with 1 being the highest).

Delay in manufacturing or delivering product	____________
Increased operating cost	____________
Loss of business/sales opportunity	____________
Loss of revenue	____________
Loss of labor	____________
Environmental impacts	____________
Perishability of lading	____________
Risk of industrial accidents	____________
Other (specify) ____________________________	____________

36) To what extent do you believe the following low-cost improvements help address or eliminate freight mobility constraints?

Actions to Respond to Constraints	No potential	Low potential	Some potential	High potential
Empowering more efficient use of labor				
Use off-peak hours for delivery/pickup				
Flexibility in hours of service—better availability of "work-arounds", waivers, spot hires, etc.				
Support labor training programs				
Upgrade communication technologies,				
Revise operating schedules—e.g. Saturday service with "traveling switch engines"				
Prepare and implement contingency plans				
Expand warehouse storage capacity				
Expand house track storage capacity				
Resolve labor-related issues				
Improve facility perimeter security				
Other (specify) ________________				

(*optional*)
Respondent's name: ____

Organization ______________________________________Title _____________________

Email ___________________________Phone ____________________________

APPENDIX E

Low-Cost Improvement Analysis Tool (LCIAT) Evaluation Form

We appreciate your time in evaluating this program. Please take a few minutes to answer the following questions to help improve the quality and utility of the program.

1. Which of the following best describes your organization (Choose one)
    - State Department of Transportation
    - Metropolitan Planning Organization
    - Deepwater Port Terminal Operator
    - Inland Waterway Operator
    - Port Authority
    - Federal Agency
    - Motor Carrier
    - Freight Forwarder
    - Logistics Services Provider
    - Warehouse Owner/Operator
    - Short Line Railroad
    - Class I Railroad
    - Shipper

	1= strongly disagree 5 = strongly agree				
2. Program is easy to install and run	1	2	3	4	5
3. The user interface is easy to understand (e.g., is the screen layout clear and easy to interpret)	1	2	3	4	5
4. It is easy to navigate through the program	1	2	3	4	5
5. User guide is easy to understand	1	2	3	4	5
6. The program is useable without user guide	1	2	3	4	5
7. The program is useful for evaluating and selecting low-cost improvements	1	2	3	4	5
8. What aspects or elements do you find most useful?	______________________				
9. What aspects or elements do you find least useful?	______________________				
10. What aspects or elements would you like included in the program?	______________________				
11. Would you recommend this program to others?	Yes	No	Don't Know		
12. Comments.					

Email responses to: fekpee@battelle.org

Respondent: (optional) ________________________________ Date________________

Organization ________________________________ Title ______________________

Contact: Email ________________________ Phone ____________________________

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation