



Fast-Forward

Key Issues in Modernizing the
U.S. Freight-Transportation System
for Future Economic Growth

Richard Hillestad, Ben D. Van Roo, Keenan D. Yoho



Supply Chain Policy Center

A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT CENTER

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Preface

For years, improved reliability in timely delivery and the low cost of freight transportation in the United States and across its borders and ports kept logistics costs low and permitted internationally distributed manufacturing and supply with complex supply chains to operate efficiently and with minimal inventory. Projections of continuing increases in freight movement, however, indicated that, to meet future freight transportation needs, parts of this transportation system would probably need to expand capacity and increase efficiency. Since 2007, logistics costs appear to be increasing. Freight-transportation costs are an important part of the reason. In addition to concerns about future capacity, reliability, and productivity, freight transportation's robustness to natural or human-created disruptions and increasing attention to the environmental impacts of freight movement are issues to be considered.

Using publicly available data and observations of many stakeholders in the U.S. freight-transportation system, this monograph describes the current state of the system, shows projections of freight growth, discusses the determinants of capacity, examines the robustness of the system, and describes the social issues, including safety, congestion, and environmental effects. It concludes with a discussion of key freight-transportation issues that we think should be the focus of near-term attention and study to help position the United States for future economic competition.

The primary intended audience for this monograph is those involved in making choices about the U.S. transportation infrastruc-

ture. The monograph should also be useful to those desiring an overview of the evolution and state of the U.S. and international freight-transportation systems.

The RAND Supply Chain Policy Center

This research was conducted under the auspices of the Supply Chain Policy Center (SCPC) of the Transportation, Space, and Technology (TST) Program within RAND Infrastructure, Safety, and Environment (ISE). The mission of the ISE is to improve the development, operation, use, and protection of society's essential physical assets and natural resources and to enhance the related social assets of safety and security of individuals in transit and their workplaces and communities. The TST research portfolio encompasses such policy areas as transportation systems, space exploration, information and telecommunication technologies, nano- and biotechnologies, and other aspects of science and technology policy. The SCPC conducts research that helps the public and private sectors address freight-transportation issues critical to the U.S., North American, and international economies.

Questions or comments about this report should be sent to the project leader, Richard J. Hillestad (Richard_Hillestad@rand.org).

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Summary

The Need to Modernize the U.S. Freight-Transportation System

During the past two decades, increasingly efficient supply chains¹ have transformed businesses, promoting distributed, on-demand manufacturing, low-cost retail outlets with automatic stock replenishment from suppliers throughout the world, and home-shopping and home-delivery services responding to Internet ordering. This efficiency is now threatened by capacity bottlenecks in the transportation system, inefficient use of some components of the freight infrastructure, interference from commuter transport, the supply system's vulnerability to disruption, and the need to address important emission and energy constraints.²

In late fall 2007, the Supply Chain Policy Center embarked on a project to identify the key policy issues associated with improving freight transportation and its capacity in the United States. We approached this project by reviewing recent literature, interviewing many stakeholders in the system, and conducting meta-analysis of existing data and quantitative reports.

¹ A *supply chain* is the system of suppliers, shippers, transportation links, vehicles, warehouses, distribution centers, management processes, and information that connects manufacturers and retailers and that connects suppliers to manufacturers. The freight-transportation system is a crucial component of most supply chains.

² Rising fuel and labor costs also increase the freight-transportation-system cost to users and influence logistical choices by those users.

Stakeholder Views

To help focus the study, we interviewed a broad range of users, suppliers, and planners in the U.S. freight-transportation system about key issues, problems, and needs of the system.³ While many interviewees expressed views consistent with or biased toward the special interests of their particular stakeholder group, there was also considerable consistency regarding the needs and preferred approaches to modernization. With respect to the performance of the system, the significant points consistently made were as follows:

- Speed and reliability have deteriorated in the past few years, in all freight-transportation modes. Reliability was judged by most users as a key attribute in their transportation choices, sometimes more important than speed.
- Congestion in urban areas is a factor that significantly degrades freight-system performance.
- Operational improvements that increase efficiency (and reduce cost and environmental impacts)—for example, 24/7 operations at a port—are important as the most effective near-term source of increased capacity.
- Potential operational improvements vary from new labor agreements and changed regulations to various information-technology (IT) applications to increased visibility and control of the system.

³ We conducted 35 interviews, sometimes with multiple interviewee participants. We interviewed operators of many of the U.S. ports and some non-U.S. ports. We interviewed users of the freight system from different economic sectors, including large and small retailers, auto manufacturers, raw-material shippers, and chemical-product suppliers. We interviewed representatives of the various associations for components of the logistics chain. We interviewed a number of railroad executives and representatives of the trucking industry and sea shipping companies. And we interviewed local and regional transportation planners, discussing key regional initiatives, such as the Chicago Region Environmental and Transportation Efficiency Program (CREATE), a public-private partnership initiative in the Chicago area, and the Clean Truck Program to reduce port-related truck emissions in the Los Angeles–Long Beach area.

- Users also claimed that they are not adequately consulted about operational changes, infrastructure developments, or new regulations.
- There is a need for system-level consideration of changes, better data, and more transparency into the operations of private suppliers and users of freight transportation.

Stakeholders also expressed concerns about the robustness of the system:

- Many users commented that they were concerned about possible disruptions at ports and in other parts of the transportation network, but they also indicated that they did not utilize alternatives, mainly because of the lack or cost of supporting logistics infrastructure.
- Some companies have made choices to utilize multiple alternative ports (including some not in the United States) to have options in place if a disaster, labor disruptions, or other circumstances occur that would limit the port capacity or raise its costs.
- A few large users performed tabletop contingency exercises to study responses to disasters and disruptions in their supply chains.

Most individuals we interviewed were supportive of a smaller freight transportation–related environmental footprint, but had concerns and differences of opinion about how to pay for achieving it:

- Reduction of greenhouse-gas emissions through efficiency measures is consistently supported across the stakeholders because it is related to fuel savings as well. However, proposed methods of funding capital improvements to achieve efficiency, such as increased container fees, was a concern of users.

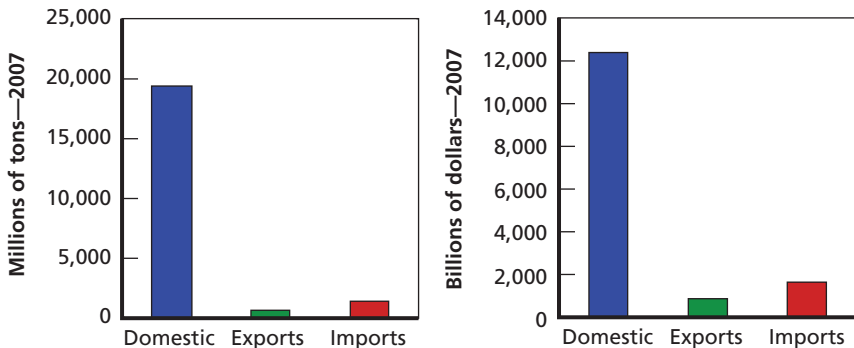
Ports realize that they must address increasing community concerns about their contributions to noise, road congestion, and pollution as a prerequisite to capacity expansion.

The U.S. Freight-Transportation System and Its Growth

The U.S. system currently moves about 60 million tons (worth about \$40 billion) per day, which is equivalent to 2.4 million truckloads per day. Because this amounts to inventory stored in the freight-movement component of supply chains, delays and uncertainty in performance of this system translate directly into increased costs of inventory and, ultimately, the cost of the goods. And changes in freight-transportation costs directly affect supply-chain costs.

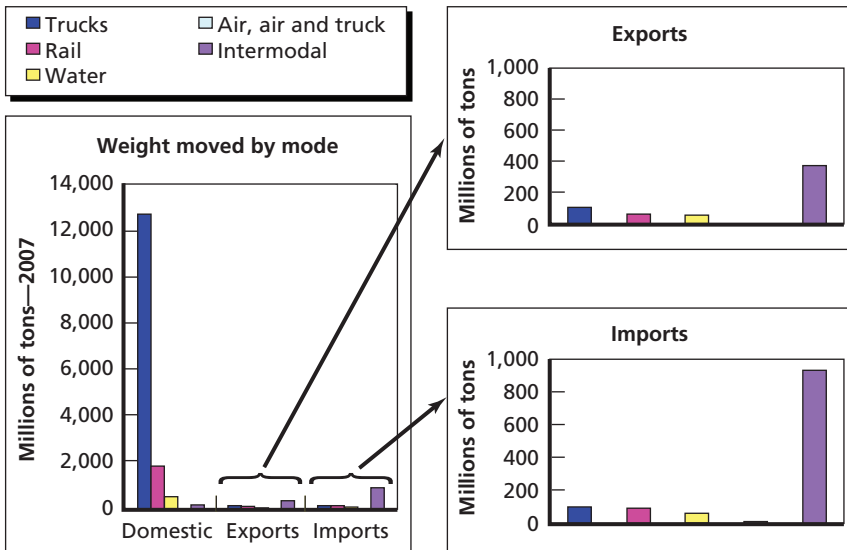
Although much attention is given in the literature to international transport of containerized freight, most freight movement is domestic—that is, going from a domestic source to a domestic destination. Figure S.1 graphs this fact. And most of the goods are carried by truck, as shown in Figure S.2. As to another measure, *ton-miles*, which expresses the intensity of use of the freight-transportation network (and is closely correlated with the expense), rail and road use are about the same, movement on barges on inland waterways is more significant, and air (despite long distances) is a relatively small player. See Figure S.3.

Figure S.1
U.S. Freight-Transportation Volumes, Domestic and International, 2007



SOURCE: Derived from *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

Figure S.2
Comparison of Domestic and International Shipping, 2007



SOURCE: Derived from *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

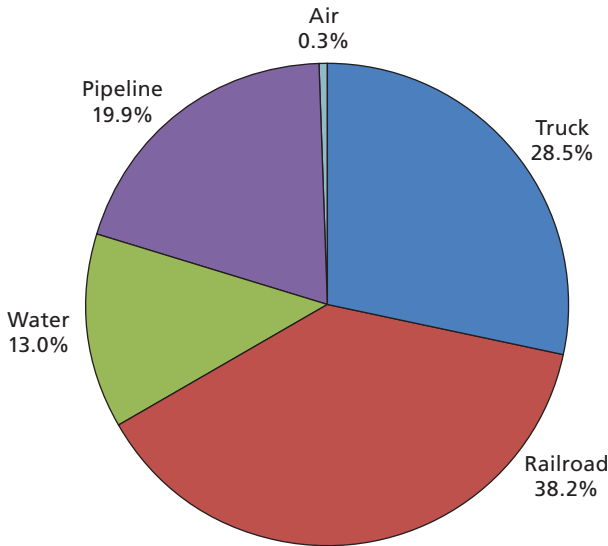
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In general, the rail system carries bulk goods and *intermodal* (i.e., movement by two or more modes) shipping containers over longer distances, whereas trucks move more-expensive, time-sensitive freight over shorter distances. Ships and barges on inland waterways generally carry bulk goods, such as grain.

The volume of freight moved across U.S. borders as a result of international trade is more than \$3.1 trillion per year. The largest U.S. trading partner is Canada—and has been for more than a decade. China recently surpassed Mexico as the second-largest trading partner; Japan and Germany are the third- and fourth-largest, respectively. Trucks carry about two-thirds of the goods traded with Canada and Mexico, as measured in value.

With respect to international trade, oceangoing, containerized cargo constitutes a significant portion of the total value of goods

Figure S.3
Comparison of Freight Ton-Miles Across Transportation Modes



SOURCE: DOT, Research and Innovative Technology Administration (2007).

RAND MG883-S.3

imported to the United States. Of the roughly \$2 trillion in imported goods for 2006, about 50 percent was waterborne (sea shipping), and, of that amount, about 60 percent was containerized cargo.

Trucking ton-miles in the United States grew by 22 percent between 1997 and 2007, and rail grew by 25 percent during the same period. However, containers moved through U.S. ports showed a 7–8 percent *annual* growth rate during the same period. Value hauled by trucking grew faster and is consistent with GDP growth.

Accompanied by this growth have been the negative social effects of large volumes of freight movement, including increased congestion, greenhouse gas and polluting emissions, oil dependency, and safety problems. And, at least in the long term, the growth and negative effects are expected to increase dramatically. The need to deal with the consequences of this growth is one of the issues we raise in this monograph.

Determinants of Capacity

Efficient freight movement throughout the United States and across its borders requires significant infrastructure and adequate capacity of the rail, highway, waterway, and port infrastructures. Delays and uncertainty associated with inadequate capacity ultimately result in the requirement for additional inventory and higher costs of manufacturing and retail goods.

The interaction between capacity, demand, and reliability (assured delivery; on time, no loss) can be complex. The users of the transportation system adapt to constraints in various ways—shifting modes, shifting demands in time and space, moving points of manufacture, choosing alternative points of entry, and changing prices. At any point in time, only some parts of the system will be constrained, permitting other parts to substitute, if feasible. Capacity is also a nonlinear function of demand, in which a little more flow on a congested link can force a tipping point at which the overall flow is dramatically reduced. Interactions between demand and capacity do not always mean a stoppage of flow, but they do increase costs, add uncertainty, cause delays, and decrease demand. Thus, any study of the capacity, reliability, and consistency of the freight system requires a corresponding study of the pattern and flexibility of the demands on the system.

Until recently, most data and projections have indicated that the capacities of ports, highways, and railroads were beginning to be limiting factors in freight movement, especially in urban areas, and, extrapolating from growth history, will be severely constraining in the next 15 to 25 years. Although the current severe economic recession has reduced the growth projections and made capacity concerns less immediate, even the revised long-term growth projections will continue to imply large future demands for freight transportation and concerns about future capacity. Consider the following projections of demand and capacity for highways, railroads, and ports.

Highways

As we have shown, trucking is the primary mode of travel for most freight. Trucking growth in weight hauled is expected to double

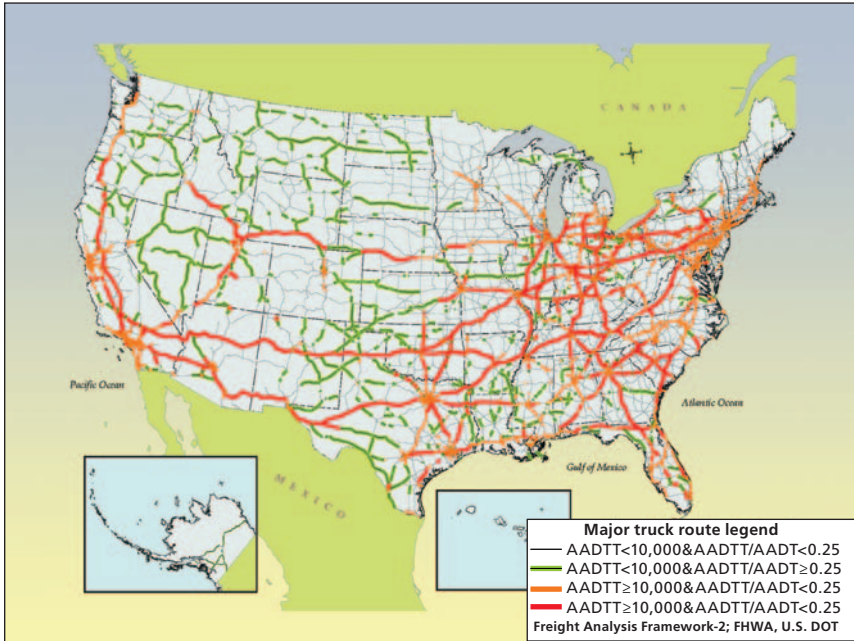
between 2002 and 2035. The average annual road delay in the United States per peak-period traveler increased from 14 hours per year in 1982 to 38 hours per year in 2005. In some urban areas, it can be much worse. In Los Angeles, for instance, it is 72 hours per year. This delay not only adds to the time and uncertainty in goods shipment but also leads to other inefficient practices, such as servicing routes with multiple trucks to meet pickup and delivery schedules that could otherwise be handled by a single truck. Of course, this adds to the congestion as well as the cost. Figure S.4 illustrates the U.S. Department of Transportation (DOT) estimate that, by 2035, approximately 14,000 miles on the National Highway System (NHS) will see a volume of at least 10,000 trucks per day, with more than one in every four vehicles being a truck. This means that more than 8 percent of the NHS will have a high volume, and a large percentage of that volume will be trucks.

Rail

Although the physical U.S. rail network has contracted from its peak of approximately 254,000 miles in 1916 to 141,000 miles today, several technological and operational advances have improved the productivity of the rail network and have actually increased the effective capacity of the network. Nevertheless, without further enhancements to capacity (although not necessarily more track), the Association of American Railroads (AAR) predicts that, by 2035 (using 2005 as a base), there will be a projected volume increase in rail freight of 88 percent more tonnage.⁴ In this case, without increasing rail infrastructure capacity, approximately 55 percent of the national rail network will be operating near or above capacity, with significant resulting delays and limited ability to accommodate maintenance of tracks and equipment. The implications of such capacity overload go beyond rail in that highways may be forced to handle not only the expected growth in truck traffic but also growth in moving goods that would otherwise be expected to travel by rail.

⁴ The 88-percent increase for rail is consistent with the 100-percent increase in freight-tons moved that was projected for the freight system as a whole.

Figure S.4
Concentration of Trucks and Routes on the National Highway System in 2035



SOURCE: *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

NOTES: AADTT = average annual daily truck traffic, and includes freight-hauling long-distance trucks, freight-hauling local trucks, and other trucks with six or more tires; AADT = average annual daily traffic, and includes all motor vehicles.

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Ports

Linear projections of the 7- to 8-percent annual increases in container handling experienced by the ports between 1997 and 2007 would require the major ports to process as much as four times the number of containers in 20 years. The current drop-off in container movements at the ports raises questions about this type of linear projection. However, even if the long-term increases are half those projected, there is a need for significant additional capacity. It appears that operational changes, such as labor agreements that would make it more feasible for 24/7

port operations, and other operational measures that spread demand and make more efficient use of port land area, should go a long way toward providing increased capacity at the ports themselves.

The real problem related to port growth is the capacity of the connecting infrastructure (the highways and rail systems linking the ports to the hinterlands) and the infrastructure's effect on the urban areas surrounding the ports. This monograph discusses a number of alternatives to enhance the capacity of port connections to the hinterlands, including the development of additional capacity at more ports and the use of alternative modes (short-haul rail and short-sea shipping) to remove and spread out the highway-connector traffic associated with the main ports.

Overarching Issues for Improving Freight Transportation and Some Implications for Policy

We suggest four freight-transportation and freight-infrastructure issues that appear to be the most significant as the nation moves forward with infrastructure developments and refurbishment to foster future economic development. Their significance is drawn from reviewing data about freight-transportation growth and factors underlying system capacity, discussions with stakeholders, a study of proposals for improvements, and review of the potential effects on measures of freight transportation.

Issue 1: Increasing the Capacity of the U.S. National and International Freight Systems Through Operational Improvements and *Selective* Infrastructure Enhancement

As shown in the monograph, long-range projections of highway, rail, and international flows of freight indicate the need for systemic improvement, a plan to use existing assets more efficiently, an improved public-private planning system and a decision to address the need for additional capacity in all parts of the freight-transportation network.

Enhancing freight-transportation capacity does not necessarily mean adding and upgrading infrastructure, such as highway lanes,

port terminals, and rail track everywhere, nor even at all apparent bottlenecks. Rather, it should be done by utilizing all the tools at hand, including regulations, pricing, and technology, and selective infrastructure improvements, to increase the overall productivity, reliability, consistency, and capacity of the system. As we noted, the important advantages of operational enhancements to capacity are that (1) they can often be implemented in the near term (in contrast to the long lead time of infrastructure-construction projects), (2) the increased productivity of the resulting system reduces costs, and (3) such productivity often reduces energy use and emissions. However, operational improvements may require additional specialized infrastructure, such as that to increase IT-based connectivity and control.

Elements of a robust solution include the following:

- Use operational tactics to mitigate freight congestion of roadways. Such tactics attempt to spread transportation demand in time and location (using congestion pricing, for example) and to reduce the overall demand (providing alternative modes and reducing packaging are two such tactics).
- Reduce passenger traffic on congested highways. Generally, passenger traffic is a significant cause of roadway freight congestion in urban areas, so decreasing freight congestion will require tactics to reduce this traffic. Such tactics include increased urban mass transit.
- Integrate freight and passenger planning on urban rail and highways.
- Provide more opportunities for mode shifts from road to rail or waterway (more streamlined and transparent intermodal connections, for example).
- Develop an IT-based “infrastructure” to facilitate freight movements across modes and increase the efficiency of the system.
- To increase rail system capacity, plan a mix of operational improvements and selected infrastructure developments, such as centralized control systems,
- To reduce the congestion and other negative social effects of moving goods to and from ports in urban areas, develop port-

connector strategies. Such strategies may include short-sea shipping and using short-haul rail to shift truck traffic from the main port.

Issue 2: Creating an Adaptable, Less Vulnerable, and More Resilient Freight-Transportation System

The transportation system will need to continue to adapt to future unknown changes in supply chains as the world economy evolves. This adaptation may include less outsourcing (depending on labor and fuel costs), shifts to U.S. Gulf and East Coast ports with the expansion of the Panama Canal, increases in exports relative to imports, and population shifts to urban areas. The system must also remain survivable and have the ability to recover quickly from disruptions of various kinds, both natural and those caused by human actions. The current recession has shown some parts of the system to be particularly vulnerable to changes in demand, and experience with disruptions suggests a system with insufficient adaptability and resilience. An important aspect of this vulnerability is the dependence on too few ports and routes for the bulk of goods movement in the United States and across its borders.

Elements of a robust solution include the following:

- Provide incentives for the use of alternative ports of entry and debarkation. Such incentives may include differential container fees, which could be used to pay for additional infrastructure development and environmental-pollution mitigation in the more heavily used ports.
- Increase system-level modeling of the U.S. freight system to include interactions between modes, regions, and components of the freight infrastructure. Such a model should be capable of simulating the reactive behavior of independent users of the freight system to congestion, prices, constraints, new infrastructure, and disruptions at nodes and links of the infrastructure. Congruent with the development of such a model would be the development of an expanded freight-data system to support the modeling.

- Identify and analyze key freight-system vulnerabilities to disruption within the transportation system and simulate possible responses to those disruptions.
- Construct infrastructure that separates freight and passenger traffic on railways and highways, particularly in urban areas. These include grade separations and rail “flyovers” to separate passenger and freight rail.

Issue 3: Addressing the Energy and Environmental Issues Associated with Freight Transportation

Reducing energy use has become an important priority for the United States: to reduce dependence on foreign oil, to accommodate the higher cost of fuel, and to be responsive to increasing concerns about global warming. Transportation is responsible for about 25 percent of the U.S. greenhouse-gas emissions, and freight transportation accounts for about 25 percent of that. The environmental impacts of local and international freight movement can be large: “In 2000, container vessels calling at the ten largest U.S. ports polluted the air with more sulfur dioxide than all of the cars in the states of New York, New Jersey, and Connecticut combined” (Bailey, 2004). Freight movement accounts for approximately half of U.S. nitrogen oxide (NO_x) emissions and 35 percent of fine particulate matter. Increasing freight-movement efficiency should reduce greenhouse gases and polluting emissions, as well as generally decreasing the cost of freight movement.

Elements of a robust solution include the following:

- Implement direct mitigation. *Direct mitigation* includes reductions in truck, ship, and rail emissions and fuel use through development of cleaner fuels, improved engines, and better aerodynamics. Driver education, training, and monitoring for efficient truck driving falls in this category, as does speed limiting through engine modifications. Providing electric shore power for docked ships and replacing diesel equipment in ports with electric equipment reduce local sources of pollution and energy use.
- Make efficiency improvements as discussed earlier under the issue of managing and improving freight-transportation capacity. Such

improvements attempt to remove unnecessary trips and miles (better routing, for example), reduce trips with no load (developing IT-based virtual container yards that alert returning truckers about where to pick up a container for their return leg, for example), provide real-time information as a way to avoid congestion, and reduce or shift demands for freight movement in time. Eliminating some packaging might reduce some demand, as could shipping more-concentrated fluid products. Increasing truckload factors through IT-based load management, scheduling, and routing could reduce local truck trips.

- Make the most efficient use of various modes of transporting freight. In cost per ton-mile, trucks are less efficient than trains and barges. To the extent that goods can be shipped economically by rail and barge rather than by truck, the energy and environmental impacts can be reduced. However, because routes available for these other modes are limited and the service they provide is generally slower and more uncertain, this alternative is inefficient for local deliveries, largely done by truck, and is difficult for most regional deliveries involving distances of less than 500–1,000 miles. However, for those goods traveling longer distances, minimizing delays due to rail-truck and truck-rail transfers within the trip (reducing dray trucking⁵ at ports, for example), provides benefits/reductions in the time and cost to move goods. Direct rail transfer from docks to distribution centers is an example of improved infrastructure to facilitate more-efficient mode use.

Issue 4: Making the Case for Public *and* Private Investment in Freight-Transportation Infrastructure and Establishing Sustainable Priorities for Funding

Generally, the funding for freight-infrastructure projects is problematic. The projects take many years or even decades to plan, gain public approval, and construct. Funding for freight-transportation projects comes from a multitude of sources—federal, state, local, and private. It also makes the coordination of support and priority-setting difficult.

⁵ *Dray trucking* is generally trucking to move containers at ports.

Often, projects have perceived and real detrimental effects (increasing congestion, noise, pollution) for one or more local constituencies during construction or after completion. Transportation-infrastructure projects that benefit primarily freight movement can be even more difficult to allocate and sustain because the indirect benefit to the economy is not an argument that the public can easily appreciate. On the other hand, projects that directly benefit both freight transportation and passenger movement can generate the local support to be successful. We discuss some examples in this report.

A lack of transparency into cost and benefit (and types of benefits—e.g., noise reduction, emission reduction, reduced energy use, congestion, jobs), owing to the extent and complexity of the U.S. freight system, is an issue to be resolved. Ultimately, developing equitable and sustainable financial strategies and priorities for freight-infrastructure development is a key aspect of the problem.

Elements of a robust solution include the following:

- Establish a framework for priorities in freight-infrastructure development and strongly link the priority developments with public benefits. The framework should include a complete set of freight-impact measures, including various economic measures (jobs, added value, costs), emissions, energy use, congestion, survivability and resilience (to man-made and natural disasters), noise, and safety. Multiple future scenarios for economic development and transportation demand need to be considered. The validity and uncertainty associated with projections of freight movement are important. Scenarios should reflect how the demands for freight shipping might change in character, location, and quantity because of such factors as future economic growth or lack of growth, new business models, or changes in population and consumer demands. Robust priority-setting would consider these alternative futures and help to define solutions that work best across the full range of possible scenarios. Priority-setting should include quantified, model-based assessment of the effect of alternatives on the freight-impact measures.

- Develop a planning process that involves all stakeholders, including the private sector, at an early stage and continuously throughout the process.
- Establish local and regional priorities in the context of the broader system model of freight transport in the United States, to consider how local and regional changes in infrastructure, costs, or constraints affect the broader freight- and passenger-transportation systems.
- Develop equitable and sustained funding approaches that utilize the best information from transportation economic theory and actual experience with the tactics (in the United States and elsewhere) and that take advantage of advanced technology (such as Global Positioning System [GPS] tracking) where appropriate. Develop public-private partnerships where possible.

The following monograph details these issues and possible solutions.

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Abbreviations

AADDT	average annual daily truck traffic
AADT	average annual daily traffic
AAR	Association of American Railroads
AB	Assembly Bill
Amtrak	National Railroad Passenger Corporation
BNSF	Burlington Northern Santa Fe Railway
BPR	Bureau of Public Roads
BRAC	Base Realignment and Closure
BTU	British thermal unit
CBO	Congressional Budget Office
CCDoTT	Center for Commercial Deployment of Transportation Technologies
CN	Canadian National Railway
CO ₂	carbon dioxide
CP	Canadian Pacific Railway
CREATE	Chicago Region Environmental and Transportation Efficiency Program
CSXT	CSX Transportation

CTC	centralized traffic control
DC	distribution center
DOT	U.S. Department of Transportation
FAF	Freight Analysis Framework
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GDP	gross domestic product
GPS	Global Positioning System
GVWR	gross vehicle-weight rating
ISE	RAND Infrastructure, Safety, and Environment
IT	information technology
KCS	Kansas City Southern
LA/LB	Ports of Los Angeles and Long Beach
LCV	longer-combination vehicle
mph	miles per hour
NHS	National Highway System
NO _x	nitrogen oxide
NS	Norfolk Southern
O/D	origin-destination
OEM	original equipment manufacturer
OTI	ocean transportation intermediary
PM-10	particulate matter with particles measuring 10 micrometers or less
POLA/LB	Ports of Los Angeles and Long Beach
PPP	public-private partnership
PTC	positive train control
RFID	radio-frequency identifier

SCAG	Southern California Association of Governments
SCPC	Supply Chain Policy Center
SCTG	Standard Classification of Transported Goods
TEU	20-foot equivalent unit
TST	Transportation, Space, and Technology
UP	Union Pacific
VCR	volume/service flow ratio
VMT	vehicle-miles traveled

Introduction

Freight-Transportation Issues

Efficient movement of freight within the United States and across its borders is a critical enabler of future U.S. economic growth and competitiveness. During the past two decades, increasingly efficient supply chains¹ have transformed businesses, promoting distributed, on-demand manufacturing; low-cost retail outlets with automatic stock replenishment from suppliers throughout the world; and home-shopping and home-delivery services responding to Internet ordering. Such efficiency is now threatened by capacity bottlenecks in the transportation system, inefficient use of some components of the freight infrastructure, interference with passenger transport, the supply system's vulnerability to disruption, and the need to address important emission and energy constraints. Truck traffic carrying containers to and from the Port of Long Beach on the 710 Freeway connector, shown in Figure 1.1, illustrates the capacity problem.

There is general agreement that the transportation infrastructure (passenger and freight) needs to be refurbished and enhanced; however, there is less agreement on how to do so, on establishing improvement priorities, and on determining approaches to funding. This monograph

¹ A *supply chain* is the system of suppliers, shippers, transportation links, vehicles, warehouses, distribution centers, management processes, and information that connects manufacturers and retailers and that connects suppliers to manufacturers. Chapter Three describes these components in more detail. The freight-transportation system is a crucial component of most supply chains.

Figure 1.1
Trucks Hauling Containers to and from the Port of Long Beach on the Interstate 710 Freeway Connector



SOURCE: Courtesy of Port of Long Beach. Used with permission.

NOTE: Generally, these containers are delivered to distribution centers for sorting and repacking in long-haul and local-delivery trucks or to a rail terminal for long-distance rail transportation to another part of the country. TEU = 20-foot equivalent unit.

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provides a broad overview of U.S. freight transportation, discusses its role in the supply chains of various types of businesses, and provides data about its capacity in relation to demand for goods movement. It concludes with a discussion of four overarching system-modernization issues for accommodating future demands.

In the late fall of 2007, the RAND Supply Chain Policy Center (SCPC) embarked on a project to identify the key policy issues associated with freight transportation in the United States. At that time, the U.S. economy appeared strong, imports had been growing for many

years, and there was concern that the freight infrastructure—ports, highways, and the rail system—would soon not be capable of handling the increasing demand for movement of goods (hereinafter, goods movement).

By mid-2008, demand for transportation had moderated somewhat, and diesel-fuel prices had soared to nearly \$5.00 per gallon in the United States, causing businesses to rethink transportation-intensive supply chains involving offshore supply and manufacturing, look for ways to employ lower-cost transportation modes, and consider reconfiguring their supply-chain networks with respect to ports, routing, distribution centers, and the like. Logistics costs, which had been decreasing for more than two decades, were increasing (Wilson, 2008). The simultaneous reduction in demand and increase in fuel costs further exacerbated the capacity problem, because shippers and truckers had limited ability to raise prices to match their costs, causing some of the ocean and surface transportation fleet to be retired or mothballed (Wilson, 2008).

Fast-forward to the late fall of 2008, in which a considerably different picture of the urgency of infrastructure expansion emerged. The large, worldwide economic contraction dramatically reduced freight-transportation demand, and much of the logistics industry contracted with it. Trucking demand was greatly reduced (see Box 1.1), despite the fall in diesel prices back to 2007 levels.

Port traffic and goods movement on surface modes has decreased as manufacturing and retail have slowed, providing a pause in the search for additional capacity. (See Box 1.2.)

But a new factor also entered the picture at the beginning of 2009: a concern about defining the best stimulus for moving the economy out of one of its most serious recessions. In this regard, U.S. infrastructure renewal is high on the list of suggestions for immediate job creation and for stimulating future economic development (see, e.g., Baker, 2009). So, although the motivating factors may have changed in the short run, the efficiency, capacity, and robustness of the nation's infrastructure to move freight (and passengers) remain important issues, as does the identification of the best way to achieve those characteristics and how to set priorities.

Box 1.1. TRANSPORTATION; “Recession Creates a Load of Problems for Truckers; Cuts at Firms Are Pushing More Haulers into the Ranks of Independent Operators, Spurring Bidding Wars for Fewer Jobs” (Ron White, *Los Angeles Times*, January 7, 2009, p. C1).

“After October—which is normally the busiest month on the road for the holiday season—turned out to be the worst October for hauling cargo by truck in five years. The American Trucking Assn. reported a slight rise in business in November.

But the trade group’s chief economist, Bob Costello, warned, “the freight outlook remains bleak.”

A total of 785 trucking companies with a combined fleet of about 39,000 trucks went out of business in the third quarter, bringing the number of company trucks idled in the first nine months of 2008 to more than 127,000, or 6.5% of the industry, reported Donald Broughton, trucking analyst and managing director of Avondale Partners.

“Never have more trucks been pulled off the road in a shorter period of time than in the first three quarters of this year,” Broughton wrote in his third-quarter analysis of the trucking industry.

That has pushed tens of thousands of drivers who had been on company payrolls out to compete for slices of the smaller cargo pie with the nation’s independent owner-operator drivers, who were already struggling.

“I would estimate that we probably lost work for about 100,000 drivers in the first half of 2008 when diesel hit that record high price,” said Todd Spencer, executive vice president of the Owner-Operator Independent Drivers Assn. “It’s hard to know exactly because they don’t report it anywhere. They just go away, and they haven’t been missed that much yet because the economy has been so bad.”

In general, though, the public, while supportive of infrastructure renewal as a strategic goal for restoring the economy, is not so conscious of the need to improve freight infrastructure. To most, freight

Box 1.2. “Frozen Ports in Long Beach/Singapore Mean Bleak 2010 (Update1)” (Bloomberg News, December 23, 2008)

“Chris Lytle, chief operating officer of the port of Long Beach, Calif., took in a panorama of the slumping world economy from his rooftop observation deck one day this month. Shipping cranes stood still, truck traffic trickled and a cargo vessel sat idle, moored to a pier. “You never see that,” Lytle said. “It’s quiet. Too quiet.”

Port traffic is slowing around the world—everywhere from North America to Asia—as a recession erodes consumer demand and the credit crisis chokes off loans to export-dependent companies. International trade is set to fall by more than two per cent next year, the most since the World Bank began measuring it in 1971. Idle ports are showing how quickly a collapse in trade can spread, undermining growth in each country it reaches.

September and October are typically Long Beach’s busiest months as U.S. retailers take deliveries for holiday sales. This year, September imports fell 15.8 per cent from a year earlier, October’s dropped 9.5 per cent, and November’s slid 13.6 per cent.

“Everybody expects 2009 to be a bleak year,” said Jim McKenna, chief executive officer of the Pacific Maritime Association, a San Francisco-based group representing dock employers at U.S. West Coast ports. “Now, it looks like 2010 is going to be just as bleak.”

One 57-hectare tract at Long Beach is filled with more than 25,000 new Toyotas that dealers can’t sell. Toyota, the world’s second-largest automaker, recently forecast its first operating loss in 71 years on weak demand.

Nearby, scrap metal meant for export to Asia piled up behind a fence. From the observation deck, Lytle pointed to piles of empty containers stacked four high and numbering in the thousands. Some of the dockside cranes “haven’t turned a wheel in months,” he said.

movement is an annoyance associated with long waits at rail crossings, heavy volumes of truck traffic on interstate highways, and waiting for

local delivery trucks for uncertain home delivery. This lack of appreciation of the critical role that the efficient transport of goods and supplies plays in the nation's economy is particularly problematic for the expansion and refurbishment of freight infrastructure, which often have long lead times, usually have some negative consequences for a nearby constituency, and appear to compete with other uses of public money, such as improving health care and passenger transportation.

The true effect may be far different. U.S. economic growth and competitiveness have been tied and are increasingly tied to complex supply chains and the efficiency of freight movement (Hummels, 2001). Such efficiency depends on transportation for access to markets and raw materials, for access to labor, and for provision of flexible support for a variety of ever-changing business and manufacturing models. An important issue, then, is how to engage the public as well as the private sector in setting sustainable priorities and committing resources to this important but indirect engine of the economy.

Enhancing the ability to move freight in the United States does not necessarily mean just expanding the infrastructure of roads, rail networks, and ports. We argue in this report that substantial capacity can be gained by enhancing the *efficiency* of the freight-transportation system. For example, expanded use of *positive train-control systems* (central, information technology [IT]-based systems that monitor each train and maximize the utilization of existing tracks) can greatly increase the capacity of existing track infrastructure.² Demand-spreading throughout a 24-hour day, a week, or even across months can increase the capacity to utilize ports and existing highways.³

² A study for the Association of American Railroads (AAR) estimates that centralized traffic control could increase the capacity of a single-track system with no signal control by almost 100 percent and the capacity of a double-track system by about 50 percent in a typical rail-freight corridor (Cambridge Systematics, 2007).

³ PierPASS, a nonprofit organization created by marine-terminal operators to improve congestion and air quality at the Ports of Los Angeles and Long Beach, has implemented a program called OffPeak. OffPeak charges a fee for containers moved to or from terminals during peak traffic hours. This program diverts as many as 10,000 trucks per day from local freeways during busy commuting hours.

New, agile port concepts that utilize information technology and coordinate loading and unloading of ships with multiple conveyance modes are claimed to be able to double port capacity.⁴ Vehicles can now be tracked and automatically charged based on miles traveled, time and location of use, or type of vehicle with existing technology, which can be used to change behavior and fund necessary infrastructure. Digital monitoring and routing of trucks to avoid congestion can reduce emissions, minimize travel time, and reduce delivery uncertainty. Reduced packaging and shipping of more-concentrated products could increase load factors. Thus, important issues include not only where to enhance the infrastructure but also how to motivate and obtain the infrastructure's most efficient use.

The *reliability*—arrival of goods at their destination on time and undamaged—of the current freight transportation system is also in question. In modern supply chains, reliability is critical for especially high-value items, such as electronics, which are relatively fragile and have limited shelf life due to rapid obsolescence. Data collected at the point of sale are used to pull products from manufacturers and distributors in real time. These pull systems are generally efficient and effective for both retailer and supplier, but they place enormous demands on the freight transportation system for timely and reliable shipping. Similarly, just-in-time inventory practices for manufacturing, which reduce inventories by relying on parts to arrive very close to the time they are needed, depend on high reliability of delivery. Accidents, weather, and sudden changes in supply or demand can cause serious disruptions. The late arrival of a shipment of subcomponents can shut down an entire assembly line. Local delivery companies compete on the assured timeliness in their delivery to homes and businesses, which means that it is often more important to have an assured delivery date and time than to be sometimes faster but with an uncertain arrival time. Assurance plays an important role in the selection of the mode of transport, trucks being generally more reliable than trains in this regard. It also

⁴ A full-scale demonstration of Agile Port Concepts was conducted by the Center for Commercial Deployment of Transportation Technologies (CCDoTT) at the Port of Tacoma for the U.S. Department of Transportation (DOT) and Department of Defense (DoD).

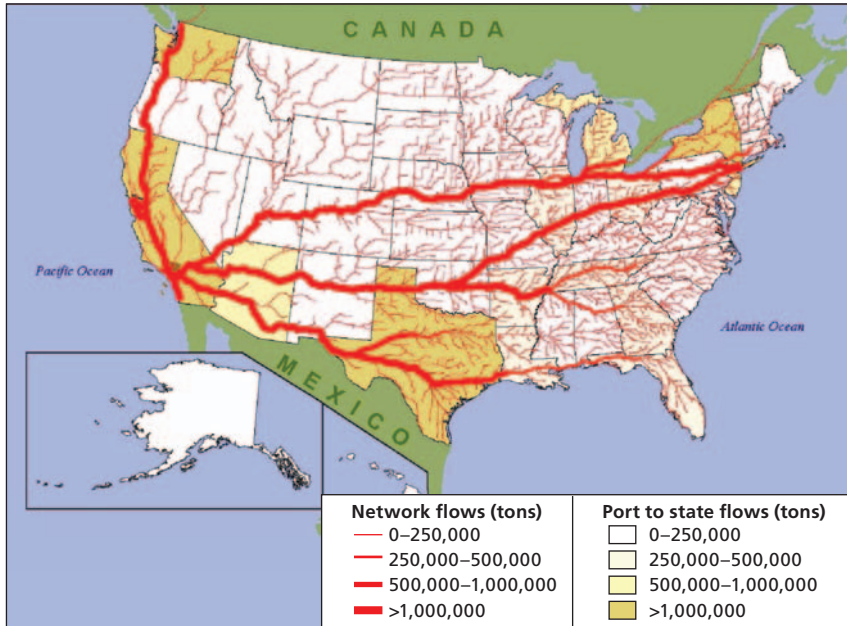
means that urban congestion that slows freight trucks (which may also be a partial cause of the congestion) has an effect greater than the immediate delay. The anticipated congestion delays can lead to inefficient delivery practices, such as sending multiple trucks and drivers to meet schedules that otherwise could be handled by one truck in the absence of the congestion uncertainty. Of course, these extra delivery vehicles exacerbate the congestion effect even more.

This concentration of traffic also focuses the negative social effects of more accidents, increased congestion, and reduced air quality on those regions through which a substantial portion of freight is passing but not consumed. The concentration of traffic also reinforces the imbalance because shipping support services and infrastructure are developed at the most-used ports and transshipment locations and are neglected in other areas, further concentrating the traffic. Figure 1.2 illustrates the heavy flow of goods through the Ports of Los Angeles and Long Beach (LA/LB) to other parts of the country. This flow is supported by the Los Angeles region's highway system, many trucking companies, local distribution centers, and a multitude of shipping and forwarding services, all of which have evolved because of the heavy goods flow. These supporting services do not exist elsewhere at a scale to permit significant diversion of LA/LB activity.

Security constraints slow goods movement at U.S. borders and ports, and new incidents that reawaken concerns will likely lead to heightened inspection requirements that could dramatically impede the flow of exports and imports (Martonosi, Ortiz, and Willis, 2005). Incidents at foreign ports supplying the United States could have effects similar to that of a failure of major U.S. ports. In addition to security, labor actions at West Coast ports have caused dramatic disruptions in the movement of goods through those ports, leaving shippers with few alternatives but to queue up and hope for quick resolution.⁵

⁵ Major West Coast ports were closed by a labor dispute from September 29, 2002, to October 9, 2002. Although some reports put the estimate of the losses to the economy as high as \$1.9 billion per day, a later Congressional Budget Office (CBO) study estimated the daily loss of a one-week shutdown at \$65 million to \$150 million per day (Arnold et al., 2006).

Figure 1.2
Trucking Volumes from LA/LB Through the Los Angeles Highway Infrastructure to the Rest of the Country



SOURCE: Federal Highway Administration, “Freight Analysis Framework” (FAF) Web page, last modified January 9, 2009.

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A third uncertainty is *nature*. An earthquake in the Los Angeles area could actually disrupt the flow of 40–50 percent of the nation’s container imports (Arnold et al., 2006). Flooding in the Midwest has, at times, closed key railroad bridges for substantial periods, with significant delays in some shipments. Thus, an important issue is the lack of flexibility and robustness of a freight system that has been optimized by its users and suppliers into a somewhat fragile system, dependent on a small number of ports and links with little short-term resilience for disruptions.

Environmental issues also figure in this third uncertainty. Freight movement generates significant greenhouse gases and is an important source of pollutants, including fine particulates and other emissions degrading local air quality (Federal Highway Administration, Office

of Freight Management and Operations, 2007). Environmental-impact reports for port expansion or the addition of highway lanes can delay projects for ten or more years. Greenhouse-gas constraints (such as California Assembly Bill [AB] 32⁶) could severely limit port operations if applied narrowly; at a minimum, they could increase the cost of goods movement if they are to be satisfied through buying credits in a greenhouse-gas cap-and-trade system. As the United States endeavors to balance national (and local) environmental objectives, reduced oil dependency, and increased economic growth, the problem of minimizing the environmental impact of freight movement will be high on the list of issues to be resolved.

The renewal and expansion of freight transportation infrastructure to date have suffered from an overall lack of *system* planning. Solutions tend to be local and stakeholder-specific and do not consider the broader system consequences and costs. For example, the social costs in safety, environmental impacts, and congestion of using trucks for transport are generally greater than moving goods by rail, yet most users do not consider such costs in their planning.⁷ Furthermore, most infrastructure planning and development is done at the local and state levels, with little national, central coordination or oversight. Indeed, the policy at the end of the George W. Bush administration was to put even more responsibility in the hands of the states (U.S. Department of Transportation Web site, Freight Transportation page, 2009). Another aspect of the system issue is that there are behavioral responses to policy actions that are not always easy to predict, such as how shippers might respond to congestion pricing on selected roadways or to increased container fees at ports meant to deal with, for example, construction of new port-area infrastructure or environmental mitigation

⁶ AB 32, formally the California Global Warming Solutions Act, was passed in 2006. The law requires that, by 2020, the state reduce its greenhouse-gas emissions to 1990 levels—roughly a 10-percent reduction from today’s levels and roughly a 25-percent reduction from a 2020, do-nothing forecast. Even more ambitiously, the law requires that, by 2050, the state reduce its greenhouse-gas emissions to 80 percent below 1990 levels. See California Assembly Bill 32 (2006).

⁷ Forkenbrock (2001) estimated the monetized social costs of trucking in terms of accidents, greenhouse gases, air pollution, and noise to be more than four times those of rail.

(Leachman et al., 2005). Without considering the adaptive behavioral responses and the system as a whole, the predicted value of policy and mitigation actions may be far off the mark.

The *system* is also broader than just the freight transportation elements. Freight transportation interfaces with the passenger transportation system in many ways. Directly, there is the interaction between autos and trucks sharing the same highways, between passenger rail and freight rail often competing for the same tracks, and railroad grade crossings impeding automobile flow. These interfaces provide both problems and opportunities. Freight solutions that improve passenger flow on highways or the rail system are likely to accrue public support that would not be there without the perceived benefit to passengers on the system. And initiatives to reduce passenger congestion have the added benefit of reducing freight delays.

Internet shopping is another example of a freight/passenger interface. Internet sales with direct home delivery reduce automobile traffic to retail stores but increase the number of delivery trucks on local road networks. But this increase may be efficient because a single truck replaces multiple personal car trips.

Nontransportation-infrastructure decisions can also affect the movement of freight. For example, to some extent, there is a choice between transporting fuel, such as coal from Wyoming, to generating plants in the Midwest and the East, and building new transmission capability that allows more generation at the fuel source. If the nation moves seriously toward renewable sources, such as solar and wind power, the transmission system will need to be expanded, which will have implications for fuel transportation. And the needs of freight transportation are constantly changing, corresponding to changes in the national and international economic systems. Ethanol production has changed the pattern of agricultural-goods movement. Increased labor costs in the Pacific Rim may be reflected in a limited migration of production back to the United States, Canada, or Mexico. Movement of the U.S. population to large urban areas and population movement to the Sun Belt mean different patterns and types of freight movement.

The various sectors of the U.S. economy use the freight system quite differently, and these differences should be considered in the

approach to freight-infrastructure renewal. The retail industry, for example, depends on sophisticated supply chains that minimize the logistics costs (inventory and transportation costs) and utilize intermodal (generally rail and truck) transport to move goods from a large variety of suppliers to retail outlets (or to the buyer, in the case of Internet sales). In recent years, the suppliers have been increasingly Pacific Rim countries, so the logistics chains are dependent on the timely, reliable, and low-cost functioning and interfacing of ports, rail, and trucks. The transportation supporting the retail sector may be limited by port capacity and highway congestion; furthermore, because it is dependent on a very few ports, it is especially vulnerable to disruption from labor actions, terrorist acts (and actions to mitigate the threat of such acts), and natural disasters.

In contrast, the agriculture and natural-resource sectors ship bulky and heavy products in which transportation is a large component of cost (8 percent, in the case of agriculture). They are dependent on reliable, low-cost transportation (mostly barge, rail, and pipeline). The natural-resource sector has other specific needs for specialized rail-cars and barges, of which the supply is limited. Rising costs of rail and maintenance of inland-waterway locks and bridges are key issues for this industry.

Competition of coal and intermodal shipments with other bulk rail-capacity-supporting chemical and raw-goods movement is an issue for this industry, as is the dispersed nature of the agricultural sector, making consolidation for efficient pickup and shipping difficult. These examples indicate that supply chains' uses of the freight transportation system differ dramatically, and best solutions to capacity issues depend on the type of industry sector being served.⁸

⁸ We note that another important customer of the U.S. supply-chain system is the military. In this monograph, we did not address the unique issues of military freight-cargo movements during peacetime or wartime.

The Questions We Addressed

Through several activities, including stakeholder interviews, literature review, meta-analysis of selected studies, and limited data analysis, we attempted to identify the key freight transportation and infrastructure issues that should be dealt with through additional research and policy emphasis. We undertook these activities partly to guide our own SCPC research and partly to inform others, including a new administration, on how to consider the freight problem and where to put the emphasis in freight-infrastructure renewal, especially as it might affect economic recovery.

The remaining chapters describe our research approach and interview results (Chapter Two); provide a quantitative description of the U.S. freight system to show the relative importance of international and domestic freight and the relative volumes of freight moved by the various modes (Chapter Three); discuss the determinants of capacity in freight transportation (Chapter Four); and, finally, present the issues we assessed as being most important for current and future development of a freight infrastructure and transportation system that will promote the efficient and flexible economic development of U.S. goods and materials (Chapter Five). We include sets of possible actions that might be taken by government and other stakeholders to enhance the decisionmaking process and move forward on the important topics.

Approach and Interview Summary

Literature Review

The subjects of freight transportation, freight infrastructure, and supply chains are broad and have an extensive literature. We focused our search primarily on recent studies of the U.S. national and international systems of seaports, railroads, highways, inland waterways, and intermodal facilities. We limited the current study to ground (highway and rail) and waterborne freight movement, although we recognize that there are also issues related to airport congestion and capacity that can affect the more-expensive goods shipped by airfreight. Generally, we focused on the literature of the past ten years, with emphasis on the past five years, and attempted to obtain material that reflected performance during the economic turmoil of the past year. The literature sources varied considerably in quality and *transparency* (i.e., the availability of source data and description of methods), from peer-reviewed journals to trade journals, stakeholder association reports, consulting reports, conference proceedings, commission reports, and government reports. Specific references to this material are made throughout this monograph.

Stakeholder Interviews

To encourage open and frank discussion, we utilized informal, not-for-attribution interviews of stakeholders throughout the freight logistics and transportation system. We conducted 35 interviews, sometimes

with multiple interviewee-participants, interviewing operators of many of the U.S. ports and some non-U.S. ports. We interviewed users of the freight system from different economic sectors, including large and small retailers, auto manufacturers, raw-material shippers, and chemical-product suppliers. We interviewed representatives of the various associations representing components of the logistics chain; a number of railroad executives and representatives of the trucking industry and sea shipping companies; and local and regional transportation planners, discussing key regional initiatives, such as the Chicago Region Environmental and Transportation Efficiency Program (CREATE), a public-private partnership in the Chicago area, and the Clean Truck Program to reduce port-related truck emissions in the LA/LB area.

Our interview protocol was open-ended. We generally began with a description of the project and asked the interviewee to describe his or her role in the organization represented. We also requested information describing the organization, particularly its role in or use of the U.S. and international supply chains. We requested additional information to assess the scale of the organization's interaction with or as a component of the supply chain (e.g., volume through a port, imports, number of vehicles, locations, market share, as relevant to the particular subject). Then we discussed such issues as the following:

- What are the primary impediments in the current supply chain, and how do you deal with them?
- What are your infrastructure-improvement priorities?
- What policies and regulations do you see as the most important to change? Why, and in what way?
- Please comment on the service characteristics—timeliness and reliability—of the various modes.
- What evidence do you see of stakeholder cooperation and interference in freight movement? How can cooperation be improved?
- What role should the various levels of government play?
- What prices or surcharges would be acceptable to reduce various bottlenecks?

- What solutions have you tried or would you like to see for supply-chain disruption?

A subjective summary of the key issues and themes raised in the interviews is provided here.

- Performance of the freight transportation system:
 - Speed and reliability have deteriorated in the past couple of years, in all modes.
 - Congestion in urban areas is a significant factor in degrading freight-system performance.
 - Almost all stakeholders pointed out the importance of operational improvements that increase efficiency (and reduce costs and environmental impacts) as the most effective near-term source of increased capacity. All were ready with examples of operational enhancements, which varied from new labor agreements and changed regulations to various IT applications to increase visibility and control of the system.
 - Users claimed that they were not adequately consulted about operational changes, infrastructure developments, or new regulations.
 - Several pointed out the need for system-level consideration of changes, better data, and more transparency into the operations of private suppliers and users of freight transportation.
- Costs of freight transportation:
 - Transportation costs, driven largely by fuel costs, are causing many users to rethink their supply-chain strategies with respect to modes, offshore manufacturing, use of distribution centers, carrying more inventory, and longer sea routes utilizing an expanded Panama Canal and more U.S. Gulf and East Coast ports.
 - Users are concerned about rail rates increasing because of the strong demand for intermodal transport. Rail companies are concerned about suggestions for re-regulation.
- Robustness of the freight transportation system:

- Individual companies have made some choices to utilize multiple alternative ports (including some not in the United States) to have infrastructure in place for potential disasters.
- A few large users ran tabletop contingency exercises to study responses to disasters and disruptions in the supply chain.
- Performance of ports:
 - Stakeholders suggested that capacity could be improved with more cooperative labor agreements. Many of those interviewed believed that U.S. ports could operate with the same efficiency and productivity as the larger Asian ports, but that U.S. labor productivity and cost are key constraints.
 - The small ports attempt to compete for international freight, but the larger ports on both coasts have the important advantages of a large population of local customers and supporting infrastructure. They suggest a chicken-and-egg problem in which they cannot entice the infrastructure (rail, for example) to expand service because of low demand, but the low demand is a result of inadequate infrastructure.
- Performance of the freight rail system:
 - Most users were concerned about the service characteristics of rail, including a lack of transparency for goods movements and uncertainty about point-to-point time. They believed that one of the causes was insufficient competition among railroads.
 - Bulk-goods shippers were concerned that intermodal rail moving of containers from port cities to the hinterlands is displacing bulk shipping capacity, although the railroads argue that these two types of freight move mostly on different routes and to different sources and destinations.
- Performance of trucking:
 - Harmonizing (i.e., achieving consistency across jurisdictions) rules about trucking and allowing larger or heavier trucks would increase capacity significantly. This suggestion was voiced about cross-border trucking and with respect to differences between states. It was noted that heavier trucks do not necessarily cause more highway wear and tear because fewer trucks are required to deliver the load.

- Urban congestion is a significant issue for truckers and trucking companies, causing delays, using extra fuel, and requiring inefficient practices, such as sending multiple delivery vehicles to meet schedule when a single truck would be adequate without the congestion.
- It was suggested that freight trucking has limited ability to adjust to congestion pricing because of delivery schedules and generally fewer alternative routes.¹ One of the problems pointed out with regard to variable pricing on roadways is that it causes trucking companies to have difficulty when quoting rates to their customers.
- Environmental mitigation:
 - Stakeholders consistently supported reduction of greenhouse-gas emissions through efficiency measures, because such measures are related to fuel savings as well.
 - Ports are facing increasing community concerns about their contributions to noise, road congestion, and pollution, which make expansion of operations to add capacity problematic.
- Security:
 - Most stakeholders were concerned with theft of cargo and vehicles, not with terrorism. The primary concern about terrorism was the possibility of a more restrictive inspection regime at ports and border crossings that would slow the movement of goods. Container break-in and theft in railyards were concerns of some users. Truckers suggested that, because it is usually a nonviolent crime and quickly crosses multiple jurisdictions, truck theft has had difficulty getting adequate law-enforcement attention.
- Funding of freight-infrastructure improvements:
 - Railroads were in favor of tax subsidies for infrastructure.
 - Truckers did not like the uncertainty of variable user pricing. Tolls on new roadways are acceptable because truckers can decide whether to use the new roadways, but the truckers

¹ This is in contrast with experience in peak-period pricing at LA/LB, at which a container fee during peak periods caused significant shifts of trucking to off-peak periods at the port.

expressed concerns about retroactive introduction of tolls on existing roadways because of the additional costs these would impose on already-marginal operations.

- Public-private partnerships were considered good ways to fund some infrastructure. Participants pointed out that it was important to have early success, particularly with improvements that were visible to the public and elected officials involved.

Meta-Analysis of Existing Studies

We did not develop original data in this examination of freight transportation issues. Instead, we reviewed data presented in reports and, where possible, validated outcomes with other sources of similar data. Likewise, we cross-checked those outcomes, where possible, with calculations on existing databases, such as the U.S. Department of Transportation Freight Analysis Framework (FAF) data mentioned later. There is considerable publicly available basic data about most modes of transportation, the ports, the highway system, volumes of freight, and commodities moved. The DOT's FAF provides an estimate of annual freight moved by mode, by commodity between origins and destinations at the county level within the United States, through ports, and from and to foreign sources and destinations (DOT, Freight Transportation Web page, 2009). PIERS Global Intelligence Solutions (PIERS Global Intelligence Solutions Web site, n.d.) data are judged to provide reasonably good aggregate data about movements of freight and containers through ports. Many of the reports utilized in the BST Associates (2008) study provided aggregate data about the performance of the freight transportation system. In some cases, such as the Cambridge Systematics (2007) report for AAR, source data were privately held and unavailable for our study. In those instances, when we refer to conclusions of those studies, we indicate that we have not been able to independently verify the performance, costs, or conclusions.

When there have been multiple studies and estimates of the same system's performance, we have attempted to disclose the multiple sources of information. One observation from our meta-analysis

is that more and better data should be collected and made public by the government about the U.S. freight transportation system. Such data should include information from private-sector enterprises that play key roles in the system, such as the railroads, although they might be kept confidential for research and study purposes to avoid disclosing competitive information.

A second observation is that there is a need for detailed but broad system-level modeling of the freight transportation system, focusing on firms' behavioral responses to constraints, disruptions, policies, delays, uncertainties, and costs in using the U.S. transportation system. The commonly used linear extrapolation of demands on the system is inadequate to capture the changes businesses make (the choosing of ports of entry, degree of offshore manufacturing, and locations of distribution-center decisions are good examples) as a result of costs and changes in the transportation system.

Evolution and State of the U.S. Freight-Transportation System

Before we suggest improvements in freight transportation and its infrastructure, it is useful to describe the system and its current state. The U.S. freight-transportation system is an interdependent system of seaports, airports, highways, railroads, pipelines, inland waterways, and vehicles that support the movement of goods that are imported, exported, produced, and consumed in the United States. About \$14.3 trillion in freight value per year (approximately \$40 billion per day) and 21 million kilotons (or 60 million tons per day) were transported in 2007.¹ This translates into the equivalent movement of approximately 2.4 million trucks per day,² or 5.2 trillion ton-miles. The volume of freight moved throughout the country is large now, but it is predicted to be significantly larger in the future. The DOT forecasted that, if the value of shipments grew between 3.1 and 3.5 percent annually and the tonnage grew between 2 and 2.1 percent annually, the growth of movement value and tonnage would approximately double between 2002 and 2035. We note that the growth rates assumed in these studies did not consider a major slowdown in domestic or global economic conditions or periods of recession. We address this slowdown later but note that revised estimates by the CBO would increase the time of freight doubling by about five years.

¹ Based on data in FHWA (Federal Highway Administration), U.S. Department of Transportation (2007).

² Assuming, for illustration, that all freight is carried by trucks and that each truck carries 25 tons.

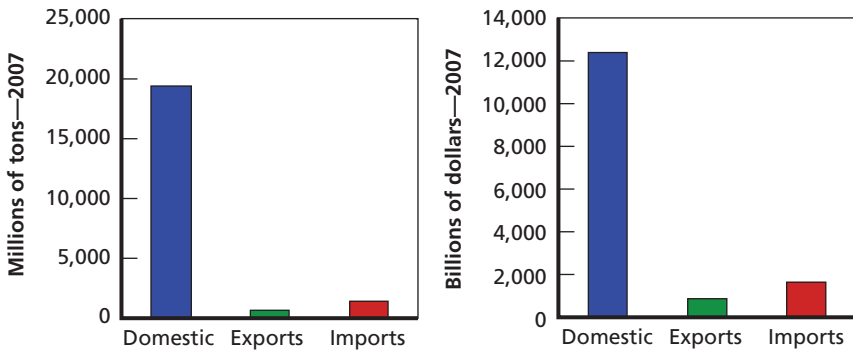
Most Freight Movement Is Domestic

Figure 3.1 shows that domestic freight movement dominates imports and exports both in weight and value—that is, by a large margin, most of the weight and value of goods movements is made up of the movement of goods within U.S. borders (Federal Highway Administration, Office of Freight Management and Operations, 2008).

Most Freight Is Moved by Truck

Figures 3.2 and 3.3 provide a snapshot of the weight and value of shipments placed on the network in 2006 (Federal Highway Administration, Office of Freight Management and Operations, 2008) for the rail, highway, and waterway networks.³ Figure 3.4 shows the percentage breakdown for domestic freight. The primary use of the rail network is to transport bulk commodities throughout the country. In 2007, bulk

Figure 3.1
U.S. Freight Weight and Value, by Domestic, Import, and Export, 2007

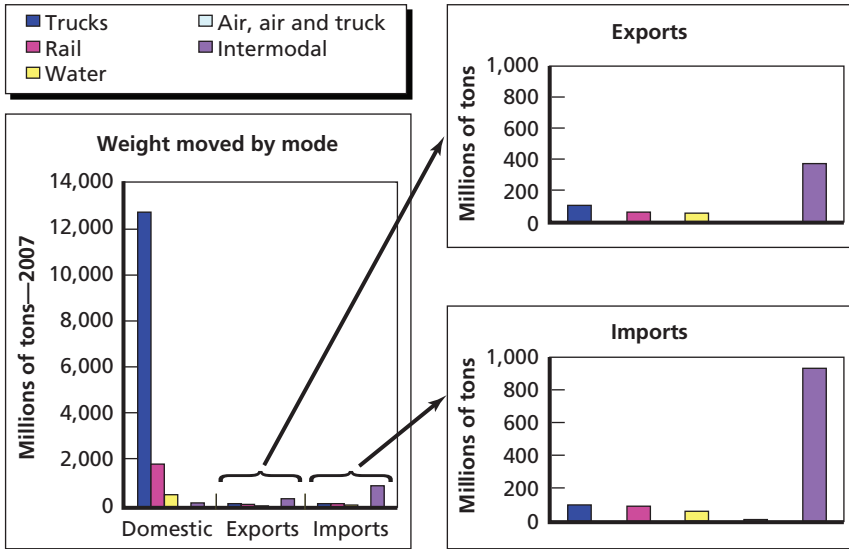


SOURCE: Derived from *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

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³ Note that the waterway movements are inland waterways and not international shipping. In this monograph, we do not address freight moved by pipeline or air; rather, we focus our attention solely on the surface supply chain.

Figure 3.2
Detail of U.S. Freight Weight, by Domestic, Import, and Export, 2007



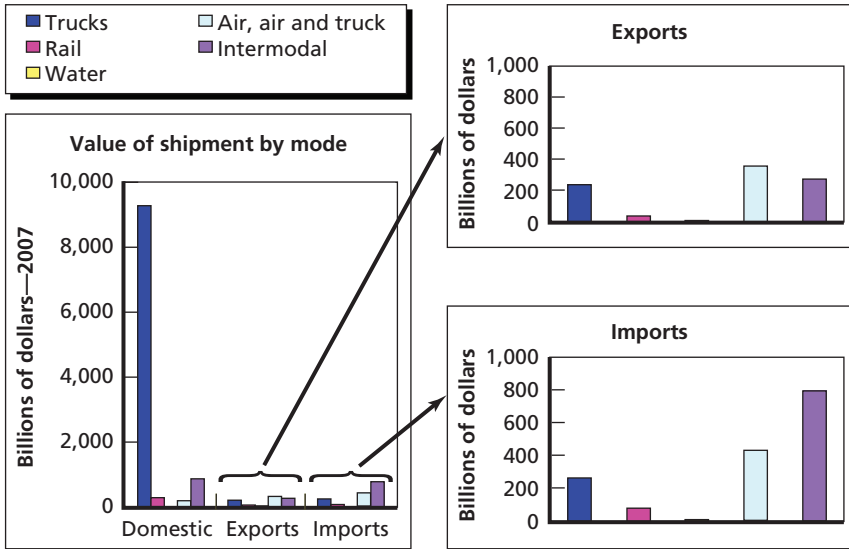
SOURCE: Derived from *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

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commodities represented approximately 44 percent of the weight placed on the rail network, yet they generated approximately only 21 percent of the gross revenue. Intermodal shipments, which often contain high-value goods brought into West Coast ports and shipped across the United States to central or eastern destinations in containers, represent 17 percent of the value of goods shipped yet only 9 percent of the weight. They are most often moved by a combination of rail and trucking.

Certain regions, industries, and goods lend themselves well to specific modes of movement or transportation routes. Moreover, there is a general correlation between the cost of shipments and the selection of shipment mode. Lower-value shipments, such as coal and grain, are more likely to move by slower means of transportation, such as rail or

Figure 3.3
Detail of U.S. Freight Value, by Domestic, Import, and Export, 2007



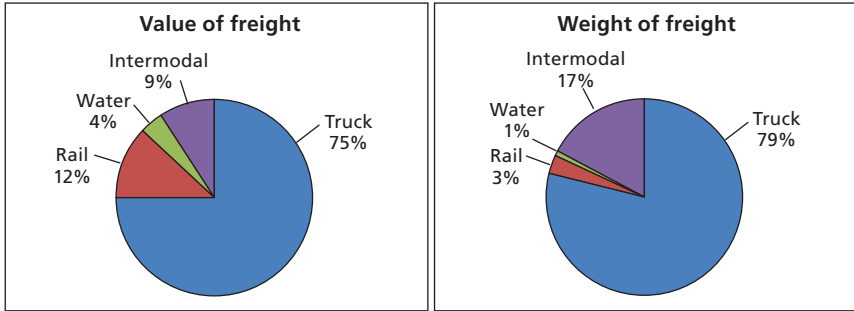
SOURCE: Derived from *Freight Facts and Figures 2008* (Federal Highway Administration, Office of Freight Management and Operations, 2008).

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inland waterways. High-value and time-sensitive items are more likely to travel via faster modes of transportation, such as truck and air. For example, a significant percentage of domestic coal consumed in the United States is mined in Wyoming and distributed to locations across the country. Coal is a relatively cheap commodity and is shipped in bulk via rail. Because the rail network is heavily used for industrial and energy production, the largest burden placed on the network in the central United States can be attributed to the distribution of coal.

Many intermodal shipments arrive at West Coast ports (primarily LA/LB) and are destined for the Midwest and East Coast. These shipments often go as intermodal freight by rail from the West Coast to large central rail hubs, such as Chicago, where they are then shipped via truck to their final destination. For those goods that are less time-sensitive or for which the cost of shipping by truck is large relative

Figure 3.4
Percentage of Value and Weight of Goods Shipped Within the United States, by Mode



NOTE: Derived from *Freight Facts and Figures 2008* (FHWA, Office of Freight Management and Operations, 2008).

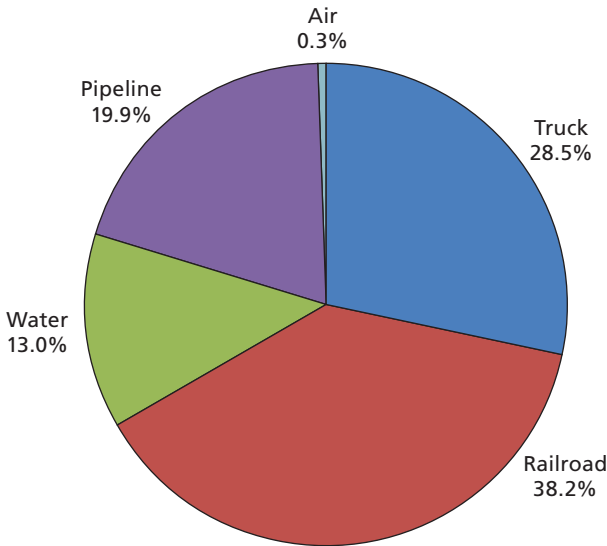
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to shipping by rail, a larger portion will see extended time on the rail network. Conversely, if the cost of shipping via truck remains relatively low for businesses or if the value of the shipments and the time-sensitive nature increase, the reliance of shipping via truck becomes increasingly likely. In recent times, because of increasing time sensitivity and flexibility, supply chains have relied heavily on trucking as the primary method of shipping.

Freight Ton-Miles Are Distributed Nearly Equally on Railways and Highways

A measurement that is used to describe the distance one short ton of freight travels within a region or country is the *ton-mile*, which measures the intensity of use of the freight transportation system and is the basis for freight-movement charges. Although trucks carry a much higher percentage of tons on the network each year, the percentage of freight ton-miles is more evenly distributed between rail and trucks. Figure 3.5 shows the percentage of freight ton-miles of all truck, rail, water, and intermodal shipments in 2005 (DOT, Research and Innova-

Figure 3.5
Distribution of U.S. Freight Ton-Miles, 2005



SOURCE: DOT, Research and Innovative Technology Administration (2007).
RAND MG883-3.5

tive Technology Administration, 2007). This figure reflects that a primary function of the rail network is to distribute heavy commodities over long distances. Dividing overall ton-miles moved by tons moved indicates that the average distance traveled for all freight in the United States is 244 miles, the average distance moved by truck is 128 miles, and the average distance moved by rail is 693 miles.

The Ton-Miles Associated with Both Truck and Rail Have Shown Substantial Growth Recently

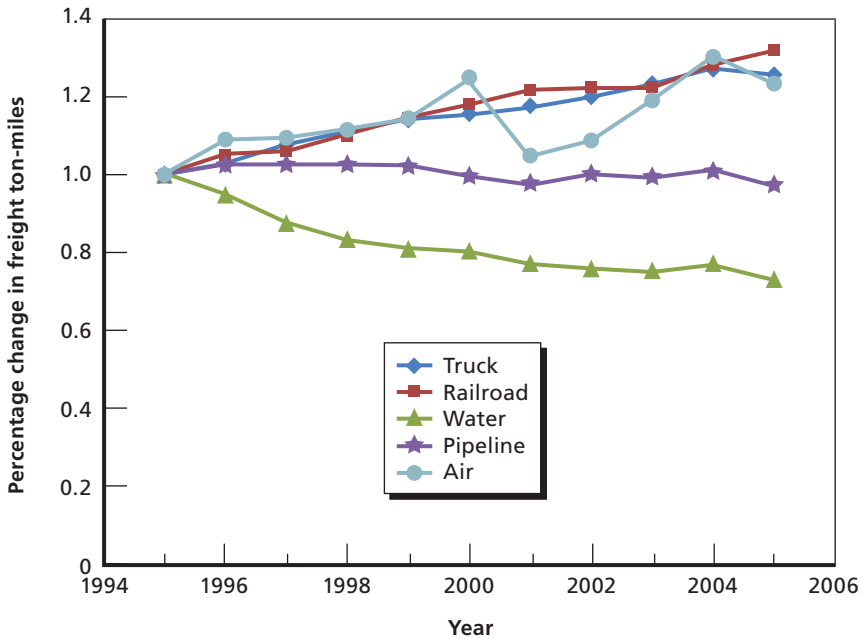
From 1995 to 2005, gross trucking ton-miles have grown approximately 25 percent while rail ton-miles have grown 32 percent. The ton-miles of airfreight also grew 24 percent, whereas the use of pipelines and inland waterways for shipping decreased 3 percent and 27 per-

cent, respectively. Figure 3.6 displays the growth of freight ton-miles by mode, from 1995 to 2005, as a percentage change of their 1995 levels.

Bulk Commodities Make Up Most Goods Movement in Terms of Ton-Miles

Using the Standard Classification of Transported Goods (SCTG), Figure 3.7 illustrates that 10 of the 42 commodity-group categories represent approximately 60 percent of the freight ton-miles distributed on the transportation network (BTS Web site, n.d.). The ten groups include bulk commodities, such as coal, cereals and grains, metals and woods, and various petrochemical products.

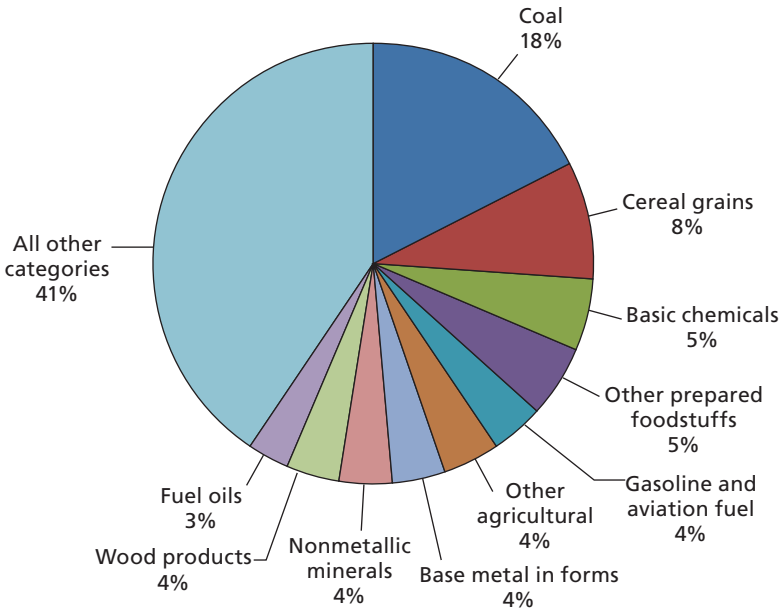
Figure 3.6
Growth of Freight Ton-Miles, by Mode



SOURCE: DOT, Research and Innovative Technology Administration (2007).

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Figure 3.7
Distribution of U.S. Ton-Miles, by Commodity Group



SOURCE: DOT, Bureau of Transportation Statistics (2004).

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Major Systems and Industries Make Up the U.S. Freight-Transportation Infrastructure

Freight Trucking and Highways

The National Highway System (NHS) is composed of approximately 162,000 miles of roads, with 46,000 miles representing the Interstate Highway System (formally, the Dwight D. Eisenhower National System of Interstate and Defense Highways). The public road system developed 75 years after the rail network began its development, with initial planning for a national highway system begun in 1921. The U.S. Army developed a list of roads and routes that it deemed critical for the defense of the nation. The development of the U.S. Numbered Highways followed into the 1930s. An important step for the development

of a series of interconnected superhighways occurred in 1938, when President Franklin D. Roosevelt asked the Bureau of Public Roads (BPR) to examine eight national corridors. The BPR report developed a set of maps that eventually became the Interstate Highway System.

The Federal-Aid Highways Act of 1956 (Public Law 84-627) authorized the development of the Interstate Highway System. The act had received strong support from President Eisenhower, who was influenced by his military experiences traveling the German *Bundesautobahn* during World War II and his belief that a well-developed road network was a critical component of a strong national defense strategy. The Interstate Highway System took approximately 35 years to complete⁴ and has come at an estimated cost of \$425 billion (2006 dollars, adjusted for inflation) (“America’s Interstate Highways,” 2008).

The NHS is the primary host to the almost 8.5 million trucks that may be on the road at any time, transporting freight across the nation (BTS, 2007b). From a weight standpoint, there are three general categories of trucks: light-heavy, medium-heavy, and heavy-heavy.⁵ In 2002, roughly 48 percent of the total trucks were classified as heavy-heavy trucks, weighing 26,000 pounds to greater than 130,000 pounds. Heavy-heavy trucks represent more than 70 percent of the vehicle-miles traveled. Middle-heavy trucks make up approximately 17 percent of the total fleet, but only 8 percent of the vehicle-miles traveled; and light-heavy trucks represent approximately 35 percent of the fleet and less than 20 percent of the vehicle-miles traveled. The largest categories of growth have come in the smallest light trucks (less than 6,001 lb) and the largest heavy trucks (130,000 lb or more).

The growth in both the heaviest trucks and lightest trucks reflects the increased use of trucks for long-haul shipments, the increased demand for time-sensitive shipments in small truck sizes, and the

⁴ Technically, some of the interstate work, including the Pennsylvania Turnpike/Interstate 95 Interchange project, has not been completed.

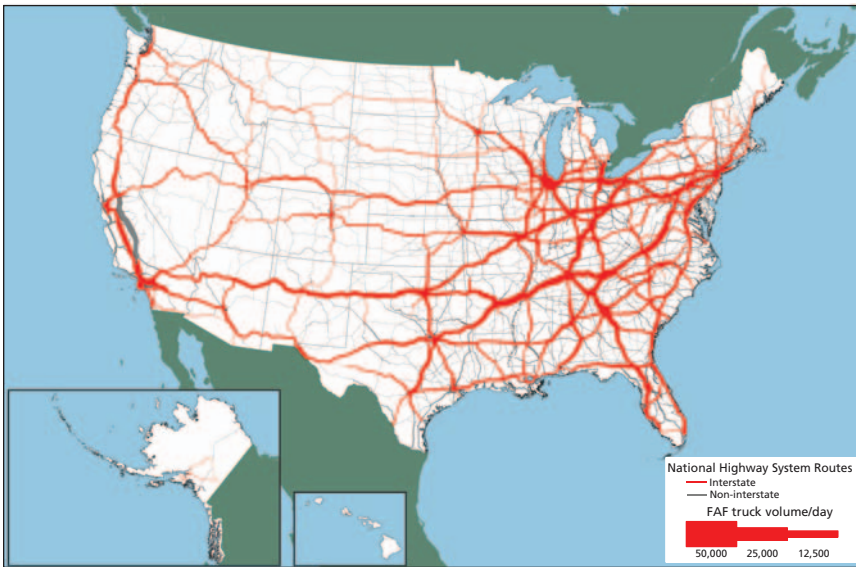
⁵ The Bureau of Transportation Statistics categorizes trucks according to their gross vehicle-weight rating (GVWR): light (up to 10,000 lb), medium (10,001–19,500 lb), light-heavy (19,501–26,000 lb), and heavy (26,001 lb and up).

increased use of hub-and-spoke distribution systems in trucking. Figure 3.8 displays the estimated daily long-haul truck traffic on the NHS.

Data from 2008 have not been weighed against these growth trends. Most likely, the growth has slowed or reversed temporarily because of fuel costs and the depth of the economic slowdown. Figure 3.9 shows the growth from 1996 to 2005.

Trucking freight has grown in ton-miles placed on the network in recent years. Between 1996 and 2005, freight-trucking ton-miles grew almost 22 percent (Figure 3.9).

Figure 3.8
Estimated Daily Long-Haul Truck Traffic on the National Highway System, 2002

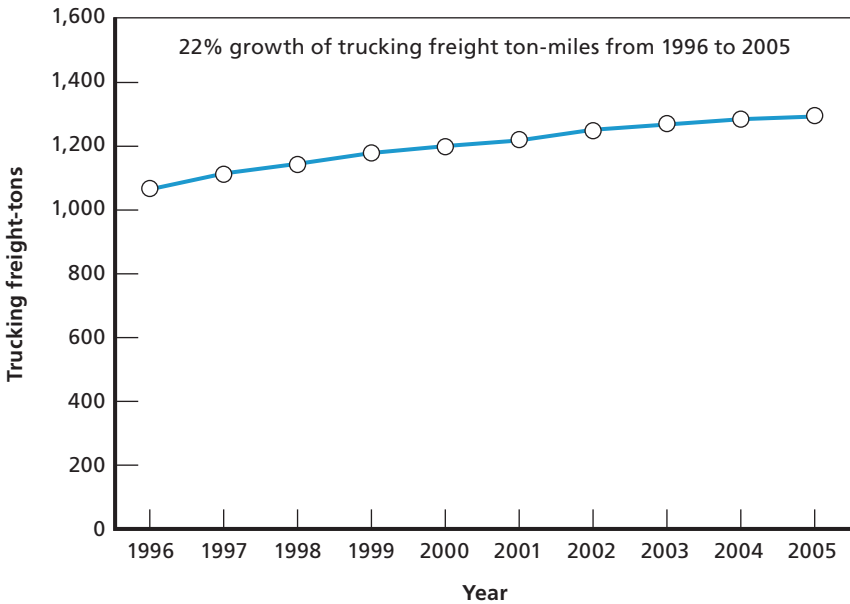


SOURCE: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 2.2, 2007.

NOTE: Long-haul freight trucks serve locations at least 50 miles apart, excluding trucks that are used in intermodal movements.

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Figure 3.9
Growth of Trucking Freight in Ton-Miles, 1996–2005



SOURCE: Adapted from Dennis (2007).

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Rail and Rail Operations

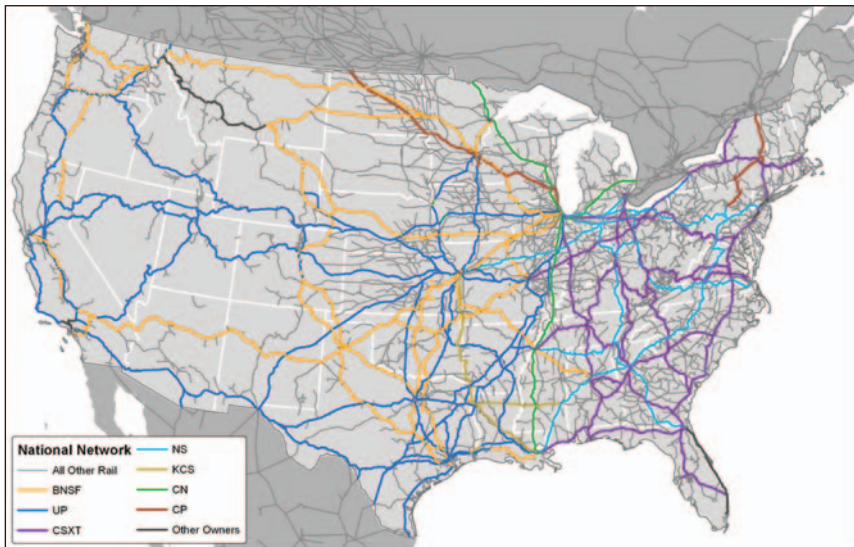
Although the highway system carries the preponderance of freight in weight and value in this country, the railroads are used primarily for movements of inexpensive commodities and bulk goods that travel long distances. The railroad industry began its growth in the United States in the second quarter of the nineteenth century. Between 1830 and 1870, the total U.S. railroad miles increased from less than 40 to approximately 50,000, including the completed transcontinental railroad (New, 2004).

U.S. freight railroads are classified into four general categories: (1) class I, (2) regional, (3) local line-haul, and (4) switching and terminal

railroads. There are seven major class I railroads in the United States.⁶ Class I lines represent approximately 1 percent of all freight railroads in the country, but they generate approximately 93 percent of freight revenue, employ 90 percent of freight-line employees, and own 67 percent of the track mileage (AAR, 2009). Figure 3.10 shows the tracks owned by the seven major U.S. class I railroads.

The physical extent of the U.S. rail network peaked in 1916, when 254,000 miles of railroad were owned and operated by class I rail-

Figure 3.10
Major Freight Corridors and Class I Railroads



SOURCE: Cambridge Systematics (2007, p. 4-1, Figure 4.1). Used with permission.

NOTE: BNSF = Burlington Northern Santa Fe Railway; UP = Union Pacific; CSXT = CSX Transportation; NS = Norfolk Southern; KCS = Kansas City Southern; CN = Canadian National Railway; CP = Canadian Pacific Railway.

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⁶ The class I railroads are defined by the DOT each year and include BNSF, CSXT, CN, KCS, NS, CP (the former Soo Line), and UP.

roads (Stover, 1997).⁷ Since that time, U.S. transportation has seen the advent of the automobile, the Interstate Highway System, and the development of air travel. Concurrently, technological advances and operational practices increased the capacity of the rail network. In the past 50 years, the network of class I railroads has decreased dramatically, falling by approximately 45 percent of its peak miles, to 140,249 in 2006 (AAR, 2006, p. 3).⁸ But at the same time, technological and operational advances improved productivity and increased the actual capacity of rail freight.⁹

In 2007, there were 33 *regional* railroad carriers in the United States, which are defined as railroads that generate between \$40 million and the class I threshold or those that own at least 350 miles of track. *Local line-haul* railroads are smaller in track miles and revenues and are defined as railroads with less than 350 miles of track and that earn less than \$40 million per year. There were 323 local line-haul railroads in 2006, most of them operating over short distances and providing point-to-point service. On average, these railroads earned less than \$5 million per year and operated less than 75 miles in a single

⁷ A *class I* railroad currently has about \$350 million or more in revenue.

⁸ Note that this figure is comprehensive; total miles of track operated includes class I, regional, and terminal railroads.

⁹ The U.S. passenger-rail network experienced its most significant historic date in 1971, when the U.S. government took over the passenger-rail services previously operated by private freight-railroad companies and formed the National Railroad Passenger Corporation, more commonly known as Amtrak. Amtrak is the primary provider of intercity passenger rail and is the sole nationwide passenger-rail service provider, operating service on approximately 21,000 miles of track across 46 states and employing approximately 19,000 people. Although Amtrak served 28.7 million passengers in 2008 and observed its sixth straight year of record ridership, the United States has one of the lowest intercity-rail usage rates in the developed world. The most recent major passenger-rail bills, the Passenger Rail Investment and Improvement Act of 2008 (H.R. 6003) (U.S. House of Representatives, pending) and the Rail Safety Improvement Act of 2008 (Public Law 110-432), were signed into law by President George W. Bush on October 16, 2008. The bills appropriate more than \$13 billion over the next five years for passenger-rail services, which include Amtrak and other intercity and high-speed rail programs. Primary goals of the legislation include general improvements to passenger-rail infrastructure and requirements, improvements to standards for reliability and on-time performance, and mandates that, by 2015, passenger trains have positive train-control systems to prevent collisions.

state. Local line-haul carriers may be connected by the final type of freight-railroad carrier, the switching and terminal carrier. *Switching and terminal* carriers are railroads that offer switching and terminal service, which consists of picking up and delivering carloads, rather than performing point-to-point services. Table 3.1 summarizes the current freight and revenue of the four classes of railroad.

Rail freight has witnessed substantial growth in ton-miles placed on the network in recent years. Between 1996 and 2005, rail-freight ton-miles grew more than 25 percent, as shown in Figure 3.11. Figure 3.12 shows that, currently, most goods carried by rail are bulk products or intermodal freight.

Because coal is the dominant product distributed by the rail network, the total tonnage placed on the rail-freight network is not distributed evenly throughout the network. Coal is mined predominantly

Table 3.1
2007 U.S. Freight-Railroad Industry Snapshot

Type of Railroad	Number	Miles Operated ^a	Employees	Freight Revenue (\$ billions)
Class I	7	94,313	167,216	52.9
Non-Class I	556	45,821	19,596	3.9
Regional	33	16,930	7,805	1.8
Local line-haul	324	22,298	5,602	1.3
Switch and terminal	199	6,593	6,189	0.8
Canadian ^b	2	561	n.a.	n.a.
Total	565	140,695	186,812	56.8

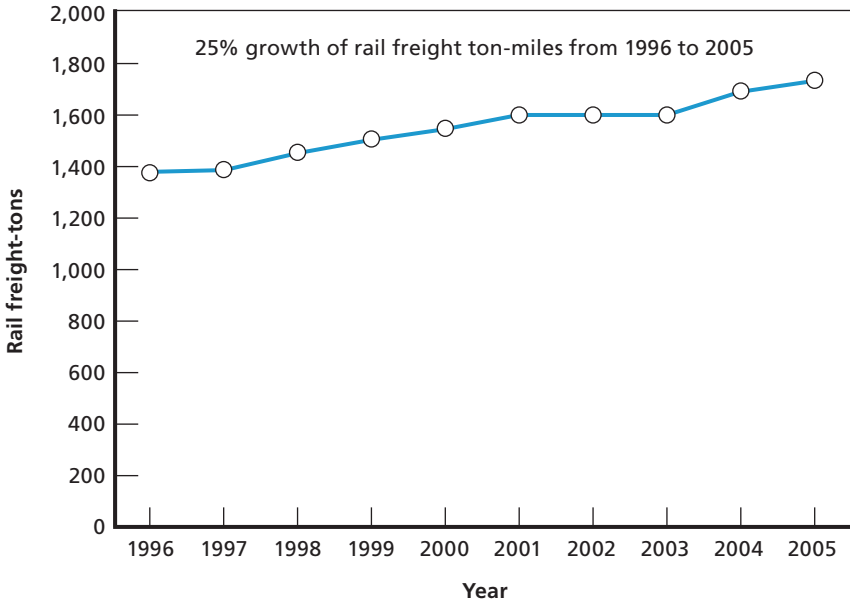
SOURCE: Data are from AAR (2009).

NOTES: n.a. = not applicable.

^a Excludes trackage rights.

^b Includes Canadian National Railway (CN) and Canadian Pacific Railway (CP) operations that are not part of a CN- or CP-owned class I carrier.

Figure 3.11
Growth of Freight Rail in Ton-Miles, 1996–2005



SOURCE: Adapted from Dennis (2007).

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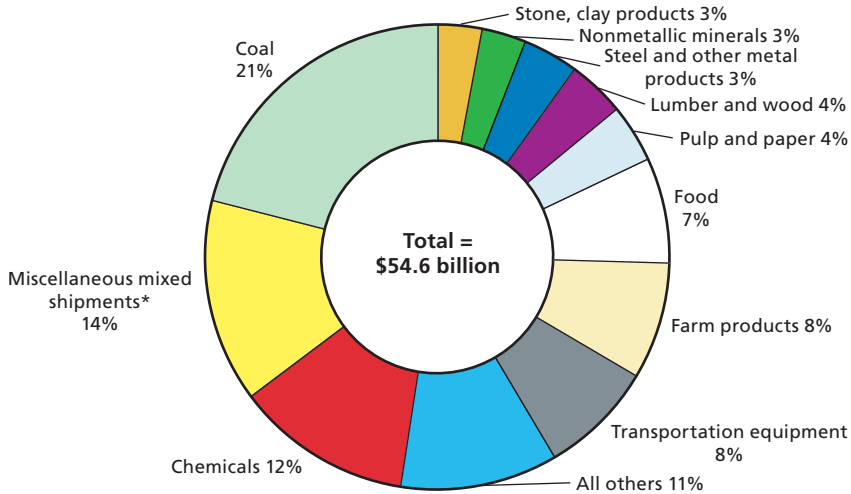
in Wyoming, so the preponderance of the weight placed on the network originates in the north central plains (see Figure 3.13).

Ports, Port Operations, and Sea Shipping

Oceangoing, containerized cargo constitutes a significant portion of the total value of goods imported to the United States. Of the roughly \$2 trillion in imported goods for 2006, 49 percent was waterborne; of that amount, 59 percent was containerized cargo (see Figure 3.14) (Arnold et al., 2006).

Containers are a significant component of international freight movement. For major ports, approximately 50 percent of the value and 15 percent of the weight of goods imported and exported are container-

Figure 3.12
2007 Class I Freight Revenue, by Commodity Type



* Mostly intermodal. Intermodal is also disbursed in individual commodity categories. Total intermodal revenue slightly exceeds revenue from coal.

SOURCE: Derived from AAR (2009).

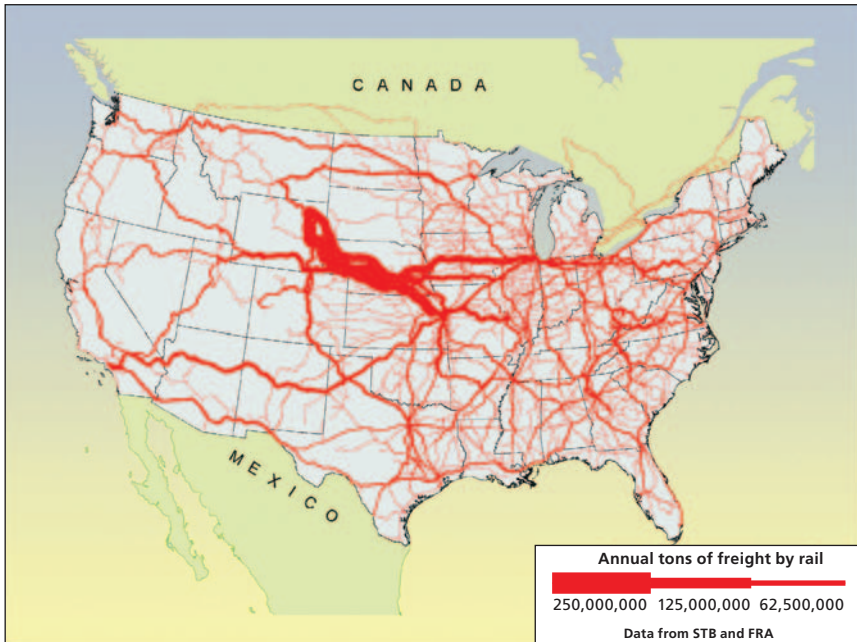
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ized.¹⁰ For LA/LB in particular, 81 percent of the value and 57 percent of the weight imported is containerized and 75 percent of the value and 67 percent of the weight exported is containerized.

Ports in the United States vary significantly in size, volume, governance, and type of cargo handled. Figure 3.15 shows the 25 ports handling the most containerized cargo in 2007, according to the U.S. Department of Transportation Maritime Administration. These top 25 ports handle 98 percent of the container trade in the country.

¹⁰ Container moves are typically measured in 20-foot equivalent units, or TEUs. Shipping containers can actually be smaller or larger than this measure.

Figure 3.13
2005 Railroad Network Tonnage



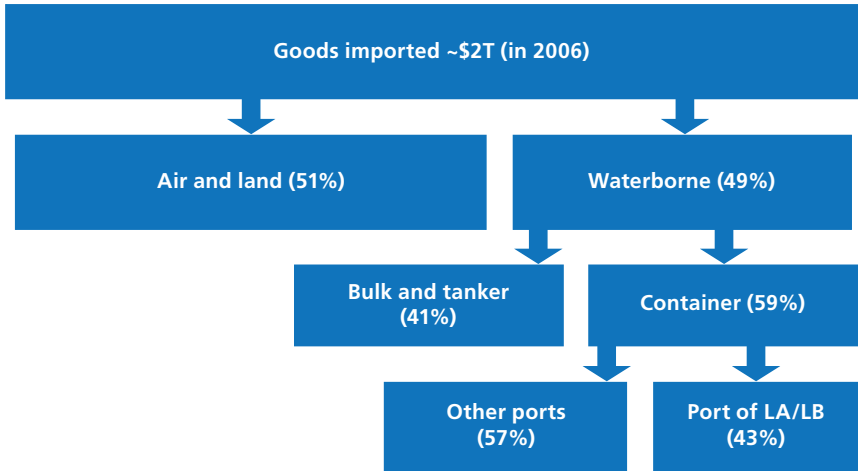
SOURCE: Derived from *Freight Facts and Figures 2007* (FHWA, Office of Freight Management and Operations, 2007, Figure 3.13).

NOTES: STB = Surface Transportation Board, Annual Carload Waybill Sample; FRA = freight rail flow assignments by Oak Ridge National Laboratory.

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The Ports of Los Angeles, Long Beach, Oakland, Tacoma, and Seattle are the dominant ports on the West Coast. Port Elizabeth, often referred to as the Port of either New York or New Jersey; the Hampton Roads port complex near Norfolk, Va.; Charleston; Savannah; and the Port Everglades and Miami ports are the dominant ports on the East Coast. Houston and New Orleans are the primary gulf ports, with New Orleans being the gateway and terminus of the Mississippi River inland waterway network.

Figure 3.14
Breakdown of Imported Goods, by Type, Value, and Mode



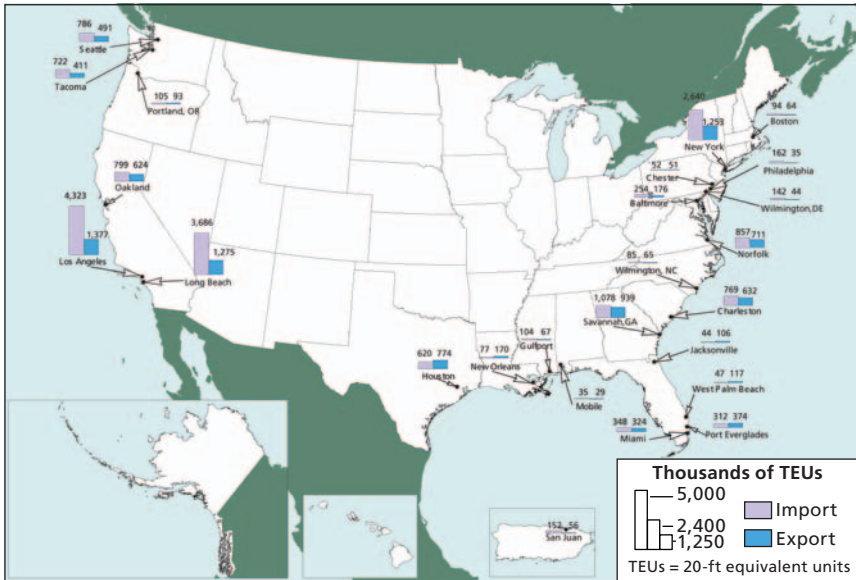
SOURCE: Arnold et al. (2006).

NOTE: T = trillion.

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Growth projections at the ports tend to focus on containerized-shipping growth. Until the recent economic downturn, container growth had increased steadily in nearly every port since 1997 (DOT, Freight Transportation Web page, 2008) (see Figure 3.16), and it has been projected to be more than double the projected increase in value shipped, because ports typically count any move of a container, whether it is full or empty. The general projections of growth at ports have been large (National Surface Transportation Policy and Revenue

Figure 3.15
Top-25 Water Ports for Containerized Cargo in 2007

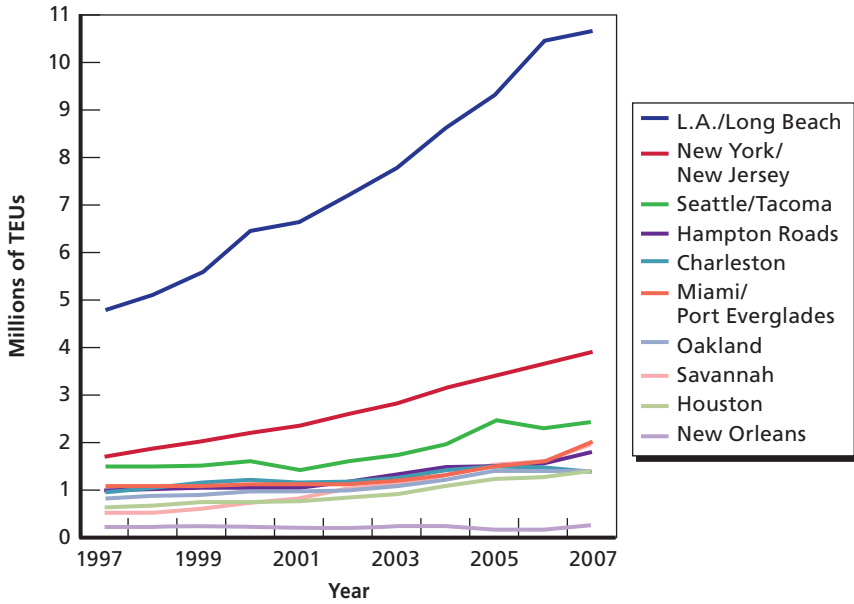


SOURCE: *Freight Facts and Figures 2008*, Federal Highway Administration, Office of Freight Management and Operations (2008a).

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Study Commission, 2008); however, these projections are linear projections and do not consider potential constraints on capacity. For the purposes of this study, we focus on the top-ten port districts: LA/LB, New York/New Jersey, Seattle/Tacoma, Savannah, Charleston, Miami/Port Everglades, Hampton Roads, San Francisco/Oakland, Houston, and New Orleans (see Figure 3.17).

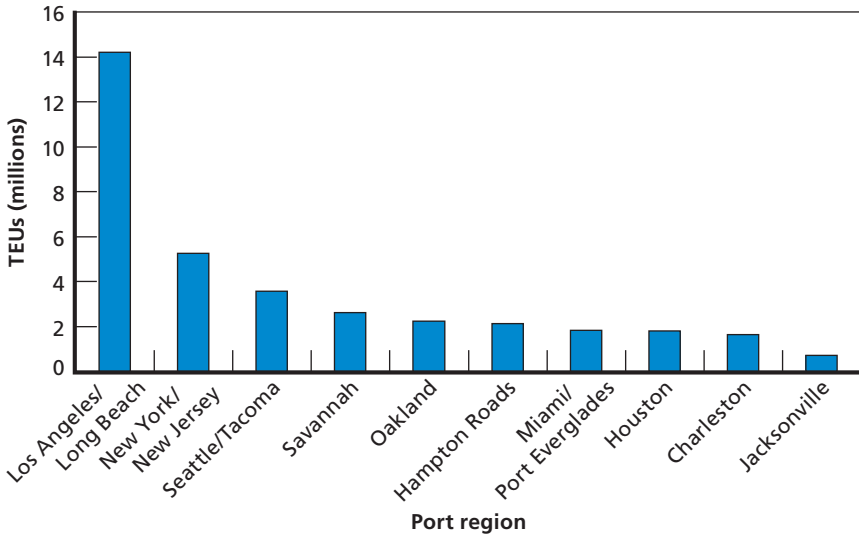
Figure 3.16
Millions of TEUs Moved, by Year, 1997–2007



SOURCE: DOT, Maritime Administration (2009).

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Figure 3.17
Top-Ten Port Regions by TEU Volume, 2006



SOURCE: American Association of Port Authorities Web site, Port Industry Statistics page (2009).

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The value of cargo handled at each port is given in Table 3.2, again with LA/LB and New York/New Jersey the dominant port districts.

Intermodal Freight Shipments

Intermodal freight shipping generally refers to the movement of goods by multiple modes of transportation. However, when used in the context of international freight, it generally means the movement of a standardized container from a port location by rail and truck. As we have shown, such freight makes up a growing and significant portion of overall rail revenue. Figure 3.18 illustrates intermodal shipments in 2005.

Table 3.2
Cargo Value of Port Regions, 2005

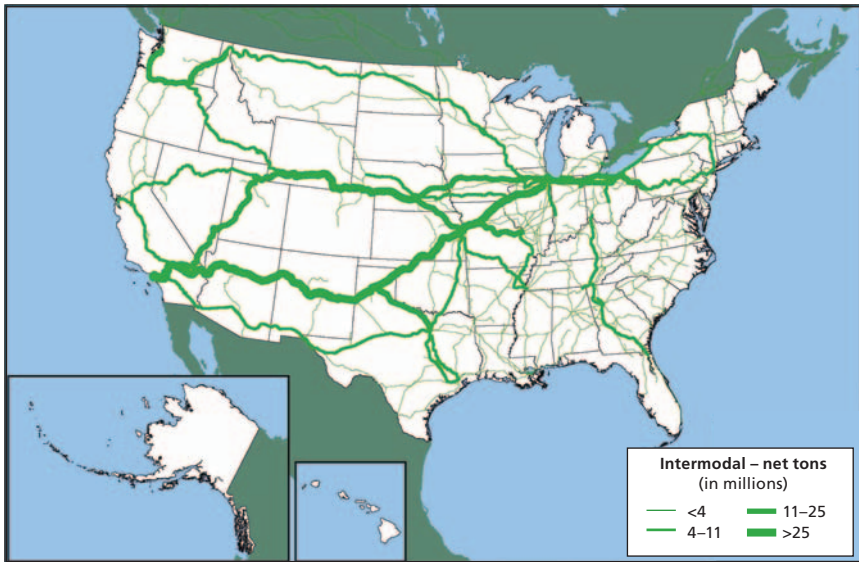
Port Region	Cargo Value (\$ millions)
LA/LB	260,250
New York/New Jersey	130,838
Houston	86,444
Seattle/Tacoma	69,088
Charleston	52,483
Hampton Roads	44,658
Miami/Port Everglades	35,197
San Francisco/Oakland	33,480
Savannah	33,424
New Orleans	20,944

SOURCE: AAPA (n.d.).

Information Systems Play a Vital Role in Long-Distance Freight Transportation

If it is to be done efficiently, coordinating the movement of goods over long distances and across multiple modes of transportation that are owned and managed by multiple public and private entities requires significant information-system infrastructure. Freight tracking; asset tracking (trucks, trains, ships); freight-terminal processing at ports, as well as drayage operations; and international border-crossing processes all require information-system support. These information systems require networks that have the capacity and bandwidth to accommodate surges in usage, the security to prevent disabling of the network or compromising of confidential information, and maintenance to ensure continuity.

Figure 3.18
Tonnage of Intermodal Movements in 2005



SOURCE: *Refocus. Reform. Renew. A New Transportation Approach for America* (DOT, Freight Transportation Web page, 2008).

NOTE: Intermodal-movement tonnage in this figure is limited to tonnage of trailer-on-flatcar and container-on-flatcar rail intermodal moves.

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International Freight Volumes

The volume of freight moved across U.S. borders as a result of international trade is more than \$3.1 trillion (see Table 3.3). The largest U.S. trading partner, for more than a decade, is Canada. China recently surpassed Mexico as the second-largest trading partner; Japan and Germany are the third- and fourth-largest partners (see Figure 3.19). Trucks carry about two-thirds of the goods, in value, traded with Canada and Mexico.

Asia has become an increasingly important trade region for the United States, particularly because more manufacturing has moved offshore. The top trading partners in Asia for 2007 are charted in Figure 3.20. China is by far the most significant U.S. trading part-

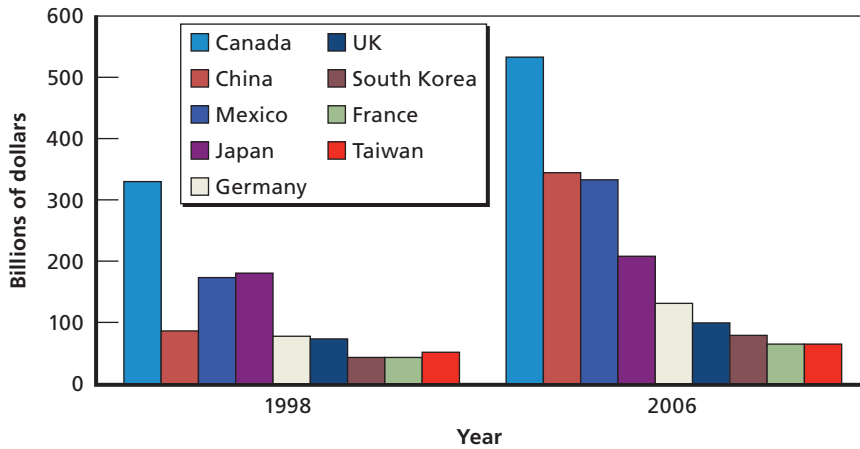
ner; Japan and South Korea are the second and third most important, respectively.

Table 3.3
Top Trading Partners in 2007: Total Trade, Exports, Imports

Rank	Country	Exports (\$ billions)	Imports (\$ billions)	Total Trade (\$ billions)	Total Trade (%)
	Total, all countries	1,163	1,954	3,117	100
	Total, top-15 countries	820	1,443	2,263	73
1	Canada	249	313	562	18
2	China	65	322	387	12
3	Mexico	137	211	347	11
4	Japan	63	146	208	7
5	Federal Republic of Germany	50	94	144	5
6	United Kingdom	50	57	107	3
7	South Korea	35	48	82	3
8	France	27	42	69	2
9	Taiwan	26	38	65	2
10	Netherlands	33	18	51	2
11	Brazil	25	26	50	2
12	Venezuela	10	40	50	2
13	Italy	14	35	49	2
14	Saudi Arabia	10	36	46	2
15	Singapore	26	18	45	1

SOURCE: U.S. Census Bureau, Foreign Trade Division (2007).

Figure 3.19
Merchandise Trade

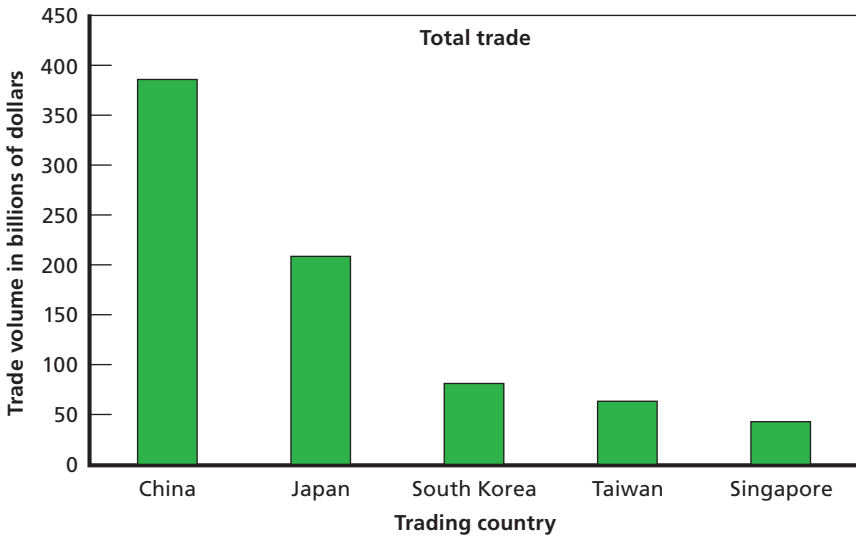


SOURCE: U.S. Census Bureau, Foreign Trade Division (2007).

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The international freight trade utilizes a number of U.S. border locations (see Figure 3.21). The ports of Los Angeles, Long Beach, New York, and New Jersey are the most significant water freight gateways; Detroit, Michigan, and Laredo, Texas, are the most significant land gateways (see Table 3.4).

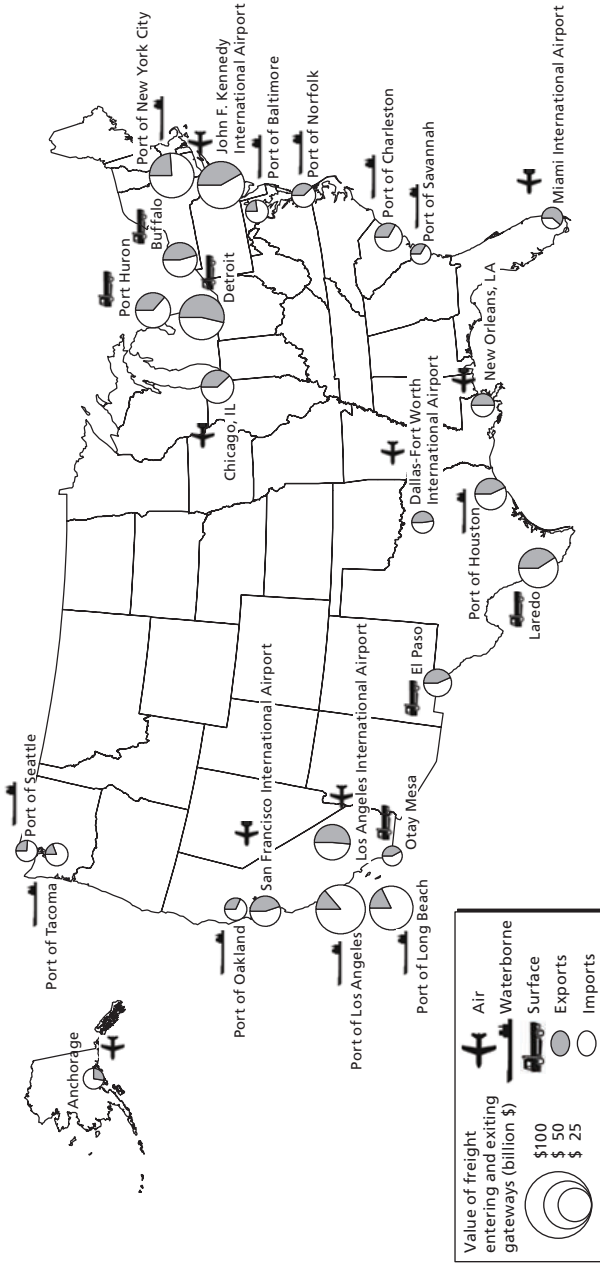
Figure 3.20
Top Trading Partners in Asia, 2007



SOURCE: U.S. Census, Foreign Trade Division (2007).

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Figure 3.21
Value of Imports and Exports Entering and Exiting Freight Gateways in 2003



SOURCES: **Air**—U.S. Census Bureau, Foreign Trade Division, special tabulation, August 2004. **Water**—U.S. Department of Transportation, Maritime Administration, Office of Statistical and Economic Analysis, special tabulations from Waterborne Databank, August 2004. **Land**—U.S. Department of Transportation, Bureau of Transportation Statistics, Transborder Surface Freight Data as of August 2004.

Table 3.4
Top Land and Water Freight Gateways, by Value of Shipments, 2005

Rank	Gateway	Mode	Exports (\$ billions)	Imports (\$ billions)	Total Trade (\$ billions)	Percentage of Total U.S. Trade at All Gateways
1	LA/LB, Calif.	Water	40	219	259	10
2	Detroit, Mich.	Land	69	62	131	5
3	New York and New Jersey, N.Y./N.J.	Water	26	104	130	5
4	Laredo, Tex.	Land	41	53	94	4
5	Houston, Tex.	Water	34	52	86	3
6	Buffalo–Niagara Falls, N.Y.	Land	33	38	71	3
7	Port Huron, Mich.	Land	24	45	68	3
8	Charleston, S.C.	Water	16	37	52	2
9	El Paso, Tex.	Land	19	24	43	2
10	Norfolk, Va.	Water	15	25	40	2
11	Baltimore, Md.	Water	9	27	36	1
12	Seattle/Tacoma, Wash.	Water	13	46	69	3
	Total		337	732	1,078	42

SOURCE: BTS (2006).

NOTE: Due to rounding, data may not sum precisely.

Social Effects of Freight Transportation

The U.S. freight transportation system enables the efficient movement of goods and commerce throughout the country to domestic and global consumers. The infrastructure that supports freight movement generates societal effects—both positive and negative—at the local, regional, national, and global levels. The social effects can be categorized several

ways, but, for the purposes of our discussion, we consider three general categories:

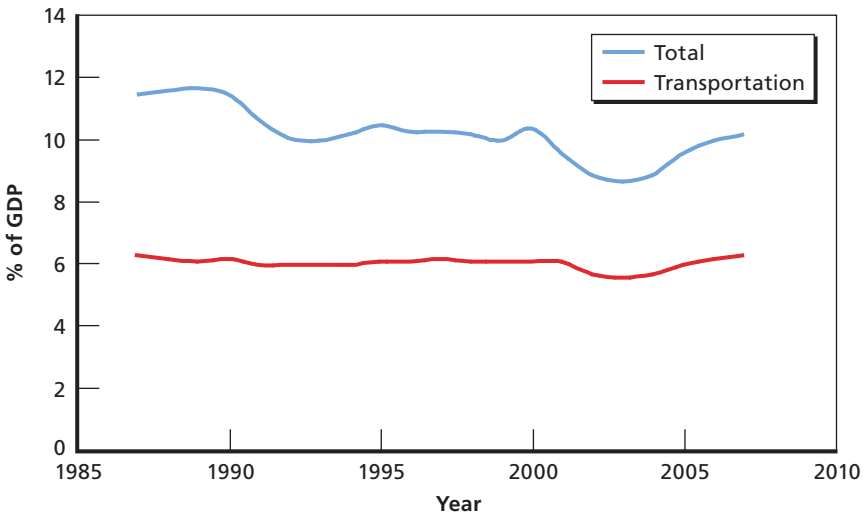
- economic effects, including employment, economic growth and costs, energy costs and consumption, and the use of land and other resources
- infrastructure and environmental effects, including sources of air, land, water, and noise pollution
- safety and community effects, including the risks and occurrences of rail, highway, and port accidents and contributions to the congestion effects on the flow of people and goods.

Economic Effects

Regions that facilitate freight transportation, such as port towns, intermodal terminal locations, and large trucking distribution hubs, experience economic growth related to the resulting transportation. Firms have benefited from an almost continuous reduction in logistics and transportation costs for most of two decades. In many cases, components of the supply chain have been decentralized, often moving offshore and frequently being outsourced to third-party logistics companies. The trend of offshoring and outsourcing has distributed the economic growth away from some of the historic manufacturing regions in the country to an expansive set of global manufacturing hubs. In some industries and regions of the country, such distribution has spurred economic growth; in other regions, it has caused economic contraction.

The argument for offshoring and outsourcing is linked primarily to lower labor costs, which outweigh increased logistics costs. When energy is cheap and goods can move efficiently through the network—which was the case for most of the past few decades—the business case for outsourcing and offshoring was often the economical choice. However, as shown in Figure 3.22, an upward trend has appeared since 2004 in the ratio of spending on transportation and logistics to gross domestic product (GDP), and there is concern that the costs of logistics and transportation could be reversing their downward trend. The

Figure 3.22
Logistics and Freight Transportation Cost Growth, 1987–2007



SOURCE: Data are from the *19th Annual State of Logistics Report* (Wilson, CSCMP, 2008).

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move to outsource more goods to distant locations has, in some cases, created greater supply uncertainty as a result of variations in manufacturing lead times, port processing times, and disruptions that occur as a result of weather, natural disasters, or work stoppages. The result of this supply uncertainty has been increased inventories to act as a buffer while maintaining customer-service levels to retailers.

Environmental Effects

The many environmental effects observed in freight movement include air emissions from trucks, railroad engines, ship engines, port equipment, and intermodal terminal equipment; noise generated by freight and rail traffic; water contamination by ships in ports and inland

waterways; and soil pollution on the supporting highways, port terminals, rail tracks, and rail and intermodal yards. For example, “[i]n 2000, container vessels calling at the ten largest U.S. ports polluted the air with more sulfur dioxide than all the cars in the states of New York, New Jersey and Connecticut” (Bailey, 2004). In addition, large port operations are often subject to higher levels of air pollution derived from the congestion of the trucks moving the cargo from port areas to inland distribution hubs or other network locations.

Although heavy-duty trucks emit smaller amounts of carbon dioxide (CO₂) emissions, they are a major source of nitrogen oxide (NO_x) and fine particulate matter (PM-10).¹¹ Diesel trucks emit about 27 percent of all NO_x emissions in the United States and one-half the emissions from mobile sources (FHWA, Office of Freight Management and Operations, 2008). Freight transportation accounts for about one-third of PM-10 emissions from mobile sources, although other sources, such as wildfires, dust from agricultural fields, and other particulates are by far the largest contributors, depending on the region of focus (FHWA, Office of Freight Management and Operations, 2008). Trucks are likely to be much more significant contributors in urban regions with ports, intermodal facilities, or hubs of transportation.

Energy Use and Greenhouse-Gas Emissions

According to a white paper on freight transportation by Cambridge Systematics, the transportation sector is responsible for 28 percent of all U.S. greenhouse-gas emissions, and freight movement accounts for 27 percent of that, with about 75 percent of the freight component associated with trucking (FHWA Web site, FAF page, 2009). Various measures attempt to compare the energy efficiency of freight movement by the various modes. *Energy intensity* is the amount of energy used per ton-mile in moving freight, measured in terms of British thermal units (BTUs) per ton-mile. FHWA, Office of Freight Management and Operations (2008a) compares the energy intensity of trucks, class I rail, and domestic waterway shipping—821, 337, and 514 BTUs per

¹¹ PM-10 specifically refers to particulate matter containing particles measuring 10 micrometers or less.

ton-mile, respectively.¹² This also indicates that trucks, in addition to moving the most freight, are the least efficient in effective energy use and greenhouse-gas emissions per ton-mile. Any attempt to reduce freight-related greenhouse gases must focus heavily on trucks.

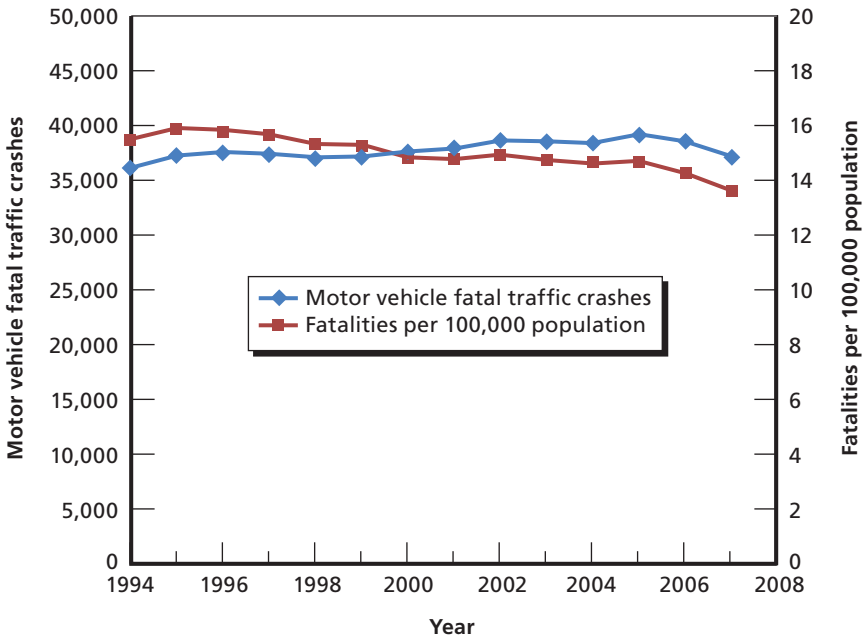
Safety

A freight transportation network also creates safety effects to communities. When high concentrations of freight are moved across roads and rail, there are often higher levels of motor-vehicle fatalities than in areas that have less freight activity. However, in the aggregate, the total number of motor-vehicle fatalities has been fairly constant over the past few decades, despite the increase in freight trucking. As shown in Figure 3.23, since 1994, the percentage of motor vehicle–related fatalities per 100,000 persons has decreased from 15.6 to 13.6 persons.

Freight movement by truck in 2005 accounted for about 10 percent of highway-related fatalities, according to a report by FHWA, Office of Freight Management and Operations (2008a). That report shows that this statistic includes the occupants of large trucks (804 fatalities) and others killed in crashes involving large trucks (4,409), compared with a total of 43,510 motor-vehicle fatalities. Railroads, including both passenger and freight trains, contributed 885 fatalities in the same period. The number of waterborne freight–related fatalities is insignificant relative to rail and truck (80 total, including passengers). In general, freight-related fatalities and injuries are a small portion of all transportation casualties in the United States. Most of the freight-related problems are associated with highways and trucking. FHWA, Office of Freight Management and Operations (2008a) also notes, “The number of crashes and other accidents in freight transportation has declined in all modes over the last quarter century *in spite of the increase in freight activity*” [emphasis added].

¹² We converted BTU per truck-mile to BTU per ton-mile, using 25 tons per truck.

Figure 3.23
Annual Motor-Vehicle Fatalities



SOURCE: Fatality Analysis Reporting System (FARS) Encyclopedia Web site (n.d.).
RAND MG883-3.23

Another way to quantify social effects of freight transportation was presented in a recent RAND report (Weatherford and Willis, 2008) leveraging a 2001 study (Forkenbrock, 2001). The study compared the total social costs of transporting a ton-mile of freight by truck and by an intermodal train. The results of the study are listed in Table 3.5.¹³

¹³ The RAND report (Weatherford and Willis, 2008) notes that many factors influence the results and that the results should not be viewed as definitive.

Table 3.5
Summary of Truck and Rail Freight Social Costs (2007 cents per ton-mile)

Mode	Social Costs, Excluding Congestion					Total
	Private Cost	Accidents	Air Pollution	Greenhouse Gases	Noise	
General freight truck	11.69	0.82	0.11	0.21	0.06	1.19
Heavy unit train	1.65	0.24	0.01	0.03	0.06	0.33
Mixed-freight train	1.67	0.24	0.01	0.03	0.06	0.33
Intermodal train	3.72	0.24	0.03	0.03	0.06	0.35
Double-stacked train	1.47	0.24	0.01	0.03	0.06	0.33

SOURCES: Forkenbrock (2001, p. 334); Weatherford and Willis (2008).

NOTE: Weatherford and Willis adjusted the Forkenbrock values from 1994 dollars, using the Consumer Price Index.

Although the Weatherford and Willis (2008) report notes the variability associated with the data used in the calculations, the underlying conclusion is that different modes of transportation do create different levels of social costs. Specifically, “intermodal trains traveling long distances have social advantages over freight trucks traveling between the same regions” (Weatherford and Willis, 2008, p. 8). The researchers noted that private shippers do not necessarily make decisions that account for the full social costs of freight-transportation pricing. That is, shippers generally choose routing and modes based on the charged transportation costs, time of transport, and uncertainty of transport and do not factor in other potential costs to society, such as emissions, accidents, energy use, or noise.

Congestion

We note that the results of the Forkenbrock study (2001) exclude congestion costs of freight transport by different modes, which can be significant. *Congestion costs* include the value of the delay that trucks impose on all of the other freight and passenger traffic on the high-

way; rail congestion delays at grade crossings on cars, trucks, and other trains; and the increases in pollution associated with congestion-based reduced speeds and idling engines. In 2002, highway congestion associated with peak-period traffic resulted in slowing below posted speed limits on more than 10,600 miles of the NHS and created stop-and-go conditions on an additional 6,700 miles (DOT, Research and Innovative Technology Administration, 2007). In 2005, congestion cost Americans \$78 billion, 4.2 billion hours, and 2.9 billion gallons of fuel (Schrank and Lomax, 2007). The exact estimate of the cost of congestion may vary among organizations, but it is clear that congestion plays a role in decreasing the performance of the U.S. transportation system and can reduce the productivity of U.S. labor forces.

Determinants of Highway, Rail, and Port Capacity

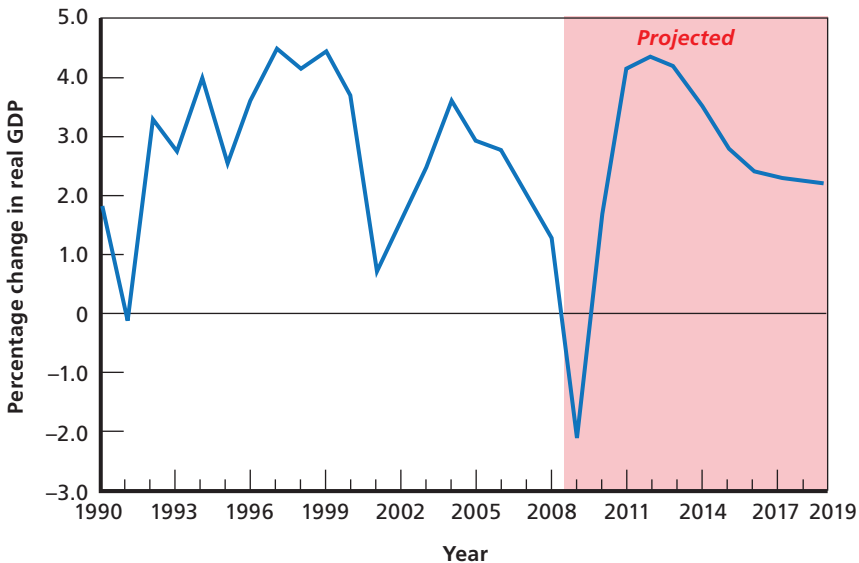
Efficient freight movement throughout the United States requires significant infrastructure and adequate capacity of rails, highways, and ports. Because many domestic and global companies have transformed their operating strategies to be more competitive by producing and holding less inventory at various stages of the supply chain, they require freight movement to be not only efficient but also predictable. Without sufficient capacity in the system, companies may observe transportation delays to manufacturing facilities, distribution centers, and retail locations. Moreover, the variability associated with transportation delays often forces companies to invest in additional inventory at stages of the supply chain. If the U.S. infrastructure struggles to meet demand in the future, U.S. domestic and global corporations will have reduced ability to compete and serve the global community.

Most projections that we show in this chapter indicate that the capacity of ports, highways, and railroads is beginning to be a constraint, especially in urban areas. Capacity will soon be a limiting factor for goods movement; consequently, it will interfere with U.S. economic growth. Although the current severe economic contraction has slowed growth projections and made capacity concerns less immediate, even the revised growth forecasts will continue to imply large future demand for freight transportation and motivate concerns about future capacity. We first take up the effects of the current economic slowdown. We then discuss other determinants of capacity and demand.

Recent Economic Slowdown

Freight-shipping projections have their basis in economic projections. Previous projections of GDP expected an average annual growth rate of 2.8 percent over the next 26 years. Recent data from the Congressional Budget Office (CBO) project a 2.2-percent *decrease* in GDP for 2009 (see Figure 4.1) and a slow recovery in 2010, which will be accompanied by an unemployment rate that will exceed 9 percent, making this period the longest recession since World War II (CBO, 2009). With real consumption expected to drop more than 1 percent (CBO, 2009), combined with high unemployment and Americans holding high levels of consumer debt, it is expected that containerized shipping volume at the ports will be low in the immediate future. Total container movements at the Port of Long Beach for the month of December 2008 were down 25.3 percent from those of the preceding year (POLB, n.d.). The

Figure 4.1
Percentage Change in Real GDP, Actual and Projected, 1990–2019



SOURCE: CBO (2009).

RAND MG883-4.1

American Trucking Associations Web site (n.d.) reported that trucking volume declined by 12.2 percent from March 2008 to March 2009.

Retail prices for the diesel fuel that trucks and some cars use have risen sharply in recent years. Between July 2002 and July 2008, diesel prices rose more than 200 percent, to more than \$4.50 per gallon, before dropping back quickly in December 2008 to just under \$2.50 per gallon. These fluctuations in diesel prices have devastating effects on independent truckers (Norris, 2008). Increases in fuel prices, together with the accompanying drop in container shipping, have also caused an increase in the number of ships being placed in layup.¹ This increase in the number of layups, combined with a significant number of ships coming out of new production, bodes poorly for the shipping industry. Recent interviews with U.S. port officials indicated that this combination of ships in layup and new vessels being delivered is an unprecedented occurrence.

Although economic forecasts are significantly lower than earlier projections, it remains likely that the U.S. supply-chain system will have difficulty supporting increased economic activities in the future—an uncertainty associated with how soon there will be a capacity crunch and not whether there will be one at all.

There Are Many Other Determinants of Capacity and Demand

Highway Freight Capacity

The capacity of freight over roads and highways is influenced by several contributing factors, including the following:

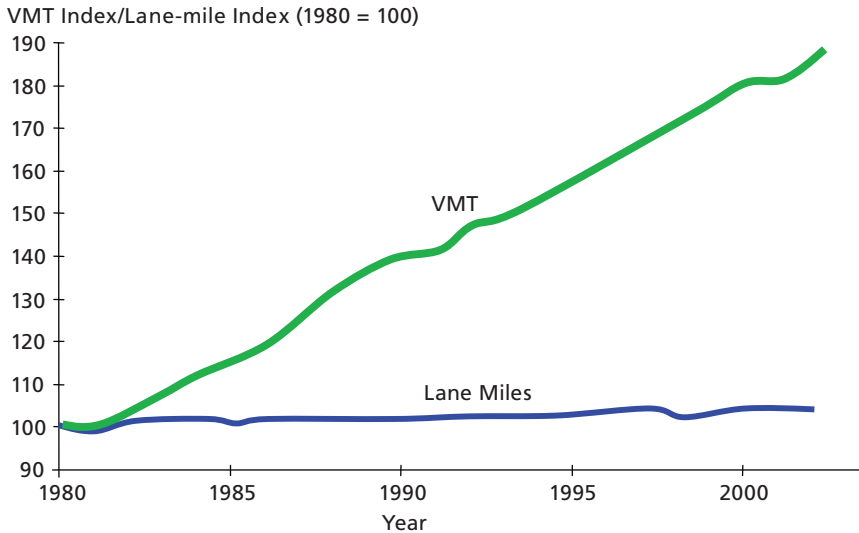
- the free flow speed of the road
- the number of lanes
- the amount of congestion on the road
- the types of vehicles that travel on the road
- the urban density that surrounds the road

¹ *Layup* refers to a ship being withdrawn from trading operations.

- the operational-speed ranges
- whether specific lanes are dedicated to certain types of vehicles (e.g., high-occupancy vehicles, dedicated truck lanes).

If we consider the growth of total traffic over the past 20 years, road-infrastructure capacity has increased at a much slower rate than the volume of road traffic. Since 1980, the route miles of public roads increased by approximately 4 percent, compared with an increase of vehicle-miles traveled (VMT) of more than 95 percent. Figure 4.2 shows the difference in the growth of VMT relative to the growth of lane-miles. Because the VMT has grown significantly more than the lane-miles of infrastructure, we can say that the utilization of the road system as a network has increased with the growth of road passenger and freight transportation.

Figure 4.2
Growth of Vehicle-Miles Traveled and Lane-Miles Created, 1980–2005



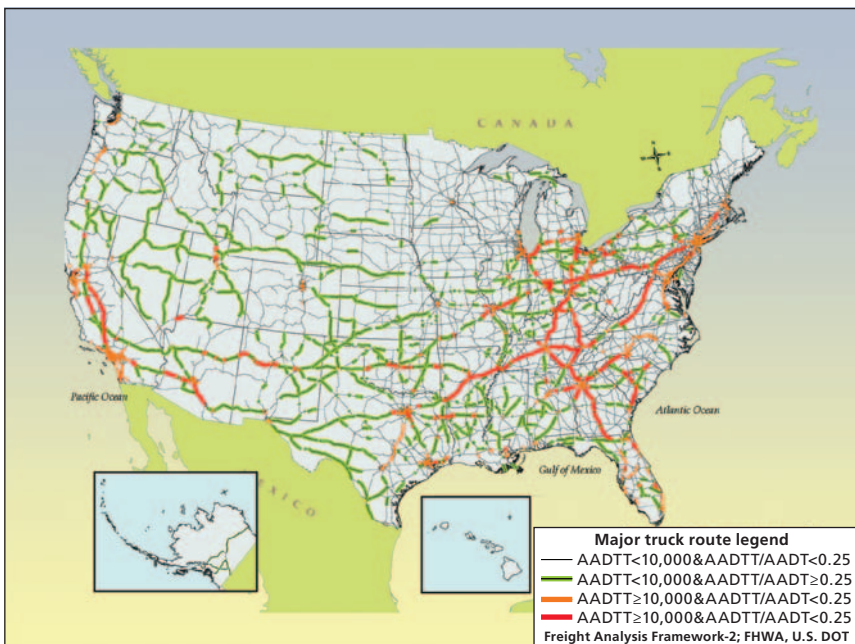
SOURCE: Cambridge Systematics (2005, Figure 2.4).

NOTE: The Index is based on 1980 being 100.

RAND MG883-4.2

Similar to the major corridors that carry rail freight, primary highway corridors are used by trucks to move freight. Figure 4.3 shows the primary truck routes on the NHS. In 2002, for those highways on which more than one in every four vehicles was a truck, approximately 4,000 of the 162,000 miles on the NHS had at least 10,000 trucks per day. This measurement provides insight not only into the volume of trucks that travel specific roads but also into the concentration of trucks as a ratio of all vehicles on the road each day. A report prepared for the Federal Highway Administration about *freight bottlenecks* (stand-still congestion of the highway by trucks carrying signifi-

Figure 4.3
Concentration of Trucks on Routes on the National Highway System, 2002



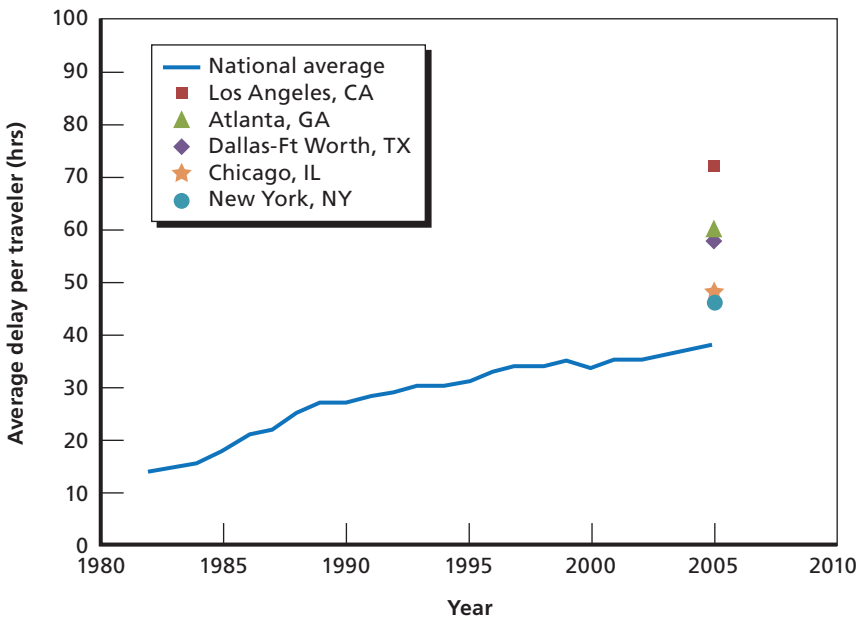
SOURCE: *Freight Facts and Figures 2007* (FHWA, Office of Freight Management and Operations, 2007, Figure 3.6).

NOTES: AADTT = average annual daily truck traffic, and includes freight-hauling long-distance trucks, freight-hauling local trucks, and other trucks with six or more tires; AADT = average annual daily traffic, and includes all motor vehicles.

cant amounts of freight) concluded that truck delays from just this cause of congestion amount to 243 million hours of delay annually. And just accounting for the trucker cost of this delay gives a direct user cost of the bottlenecks of \$7.8 billion per year (Cambridge Systematics and Battelle Memorial Institute, 2005).

Figure 4.4 shows that the annual estimated road delay per traveler has increased in the past two decades, from 14 hours per year in 1982 to 38 hours per year in 2005—an average that is a result of the increased passenger and freight movement on the NHS. The figure also illustrates some major cities that have significantly higher delays, such as Los Angeles, California (72 hours per year); Washington, D.C.

Figure 4.4
Average Annual Delays per Traveler



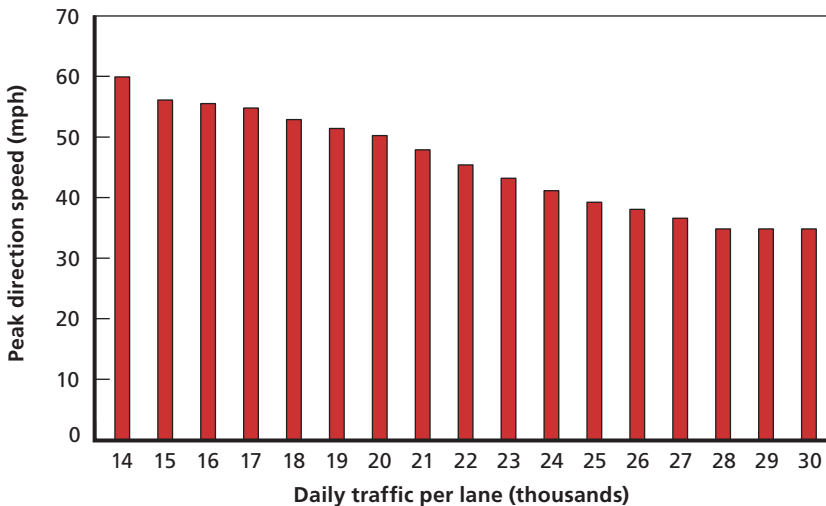
SOURCE: Schrank and Lomax (2007).

NOTE: The *average delay per peak traveler* is defined as the extra time spent traveling or riding at congested speeds rather than at free-flow speeds, divided by the number of persons making a trip during the peak period.

(60 hours per year); Dallas–Fort Worth, Texas (58 hours per year); Chicago, Illinois (48 hours per year); and New York City (46 hours per year). There is not a stated correlation between Figure 4.3 and Figure 4.4; however, as a general rule, corridors and cities with substantial amounts of daily truck traffic are likely to have higher delays on the highways.

Highly utilized roads and congested roads can create traveler delays in cities and specific corridors, but they also can affect the capacity of the corridor itself. As traffic volume increases and the utilization of the lanes and corridors increases, the traffic's average peak speed decreases, which effectively decreases the capacity of a lane or corridor. Empirical measurements of the relationship between the peak direc-

Figure 4.5
Peak Speed as a Function of Traffic Volume



SOURCE: Schrank and Lomax (2007, Exhibit 4).

NOTE: This figure includes traffic on either side of the peak traffic time and thus includes larger flows in the peak direction than those at the peak time point. The gradual decrease in peak direction speed in this graph reflects these increased flows' compensating for the slower peak flows. mph = miles per hour.

RAND MG883-4.5

tion speed² of traffic and the daily volume of traffic per lane are shown in Figure 4.5 (Schrank and Lomax, 2007). As the volume of traffic increases, the average peak speed of the traffic decreases, which reduces the *lane capacity*—the number of vehicles that a lane is physically capable of handling each day.

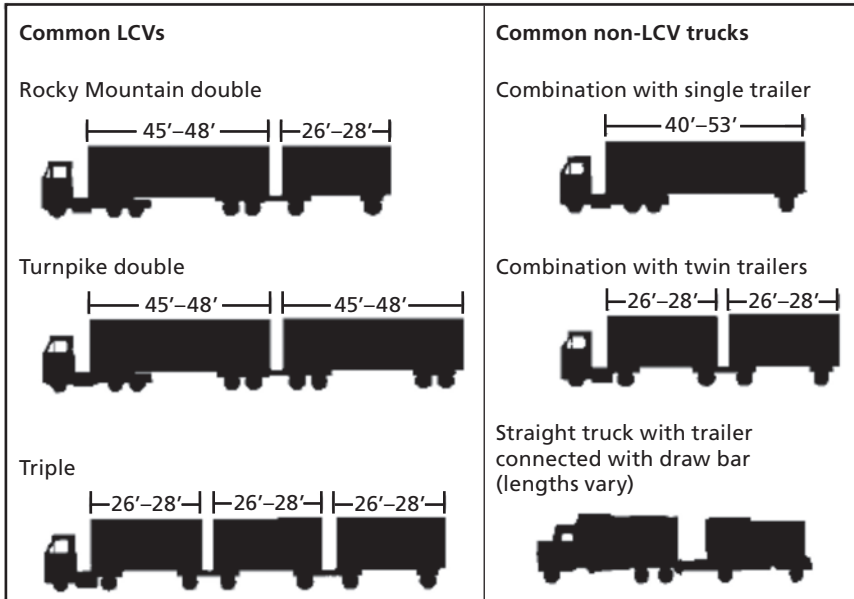
The growth in lane-miles being outpaced by the growth in VMT has lowered the average speed of traffic in many city corridors. The outcome is both congested roads and, to an extent, a reduction in capacity of the road network. However, other factors, such as the growth in the number of larger trucks, have improved the overall efficiency and capacity of the the highway freight network. One of the most recognized configurations is the standard five-axle tractor semi-trailer combination. Other, longer truck configurations, classified as longer-combination vehicles (LCVs), may also be used in some states and on specific routes for transporting goods. Figure 4.6 depicts several types of LCVs that are employed for shipping goods in the country.

LCVs offer a means of gaining efficiencies in shipping goods via truck, because it is more efficient (fuel, drivers) to ship one double or triple combination trailer than to ship two or three single combination trailers. However, LCVs may demonstrate inferior driving performance when compared with standard five-axled tractor semi-trailers. For example, LCVs may perform poorly when braking or turning at low and high speeds and may exhibit decreased stability (Ray Barton Associates Ltd. and L.P. Tardif and Associates Ltd., 2003). Concerns about the risks of LCVs and the potential for an increase in crashes led to a series of federal and state limits on the characteristics of commercial trucks used on the road system. The Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240) froze the growth of roads on the LCV network. Figure 4.7 highlights the existing routes on the U.S. Highway System that allow LCVs with specific characteristics.

The DOT projects that freight trucking will nearly double in weight and more than double in value in the 33-year span between

² Speed in the direction of peak traffic flow.

Figure 4.6
Sample Truck Configurations



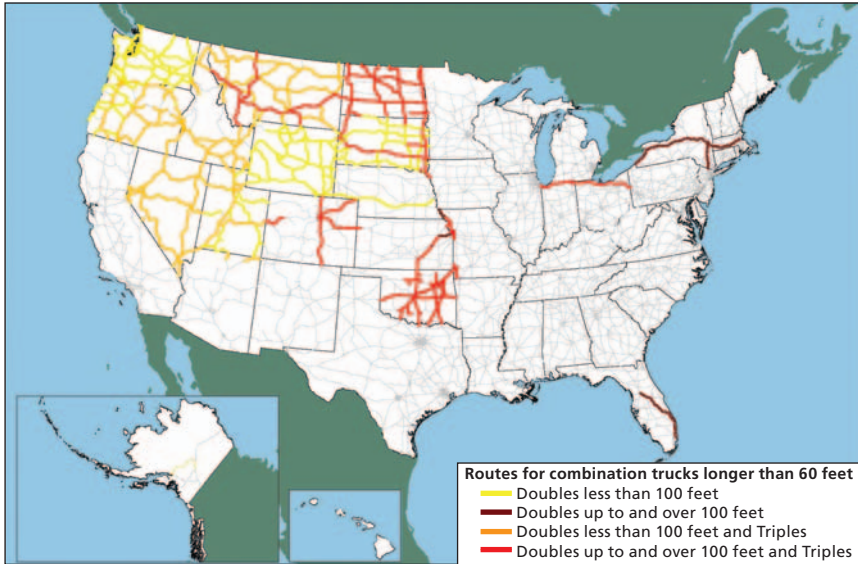
SOURCE: TranSafety Inc. (1997, Figure 1). Used with permission.

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2003 and 2035.³ Figure 4.8 shows the anticipated growth in domestic freight, imports, and exports in weight and volume. This growth would greatly increase the number of trucks on the road to support freight movement and may contribute to significant increases in highway-related congestion and wear and degradation of the roads.

³ Revised CBO projections of long-term growth estimate that the current deep recession would delay the doubling by five or more years.

Figure 4.7
Longer-Combination Vehicle Routes Permitted on the National Highway System

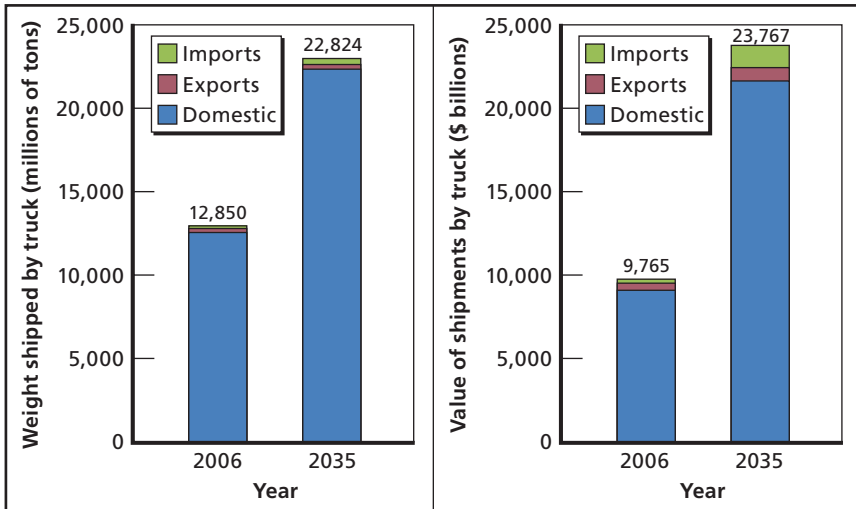


SOURCE: Federal Highway Administration, Office of Freight Management and Operations, special compilation by the Freight Operations and Technology Team (2008b).

NOTE: Empty trucks are allowed on I-80 in Nebraska.

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Figure 4.8
Estimated Trucking Freight Growth, by Weight and Value

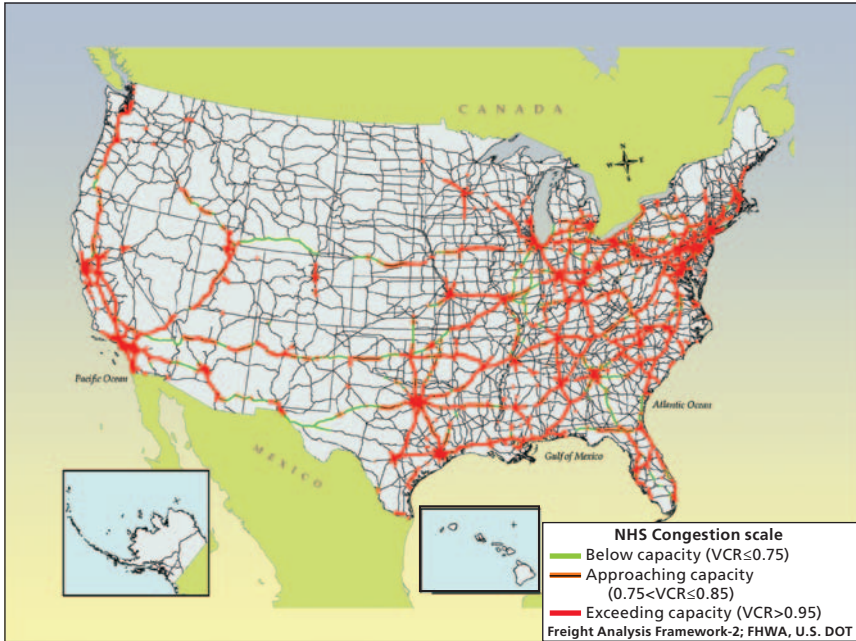


SOURCE: FHWA, FAF Web page (2007).

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Figure 4.9 illustrates the DOT estimate that, by 2035, approximately 14,000 miles on the NHS will see a volume of at least 10,000 trucks per day and, on these 14,000 miles, more than one in every four vehicles will be a truck. This means that more than 8 percent of the NHS will have a high volume and concentration of trucks. If the expected growth is not matched by improved infrastructure, passenger-traffic restructuring, trucking policies, and technology improvements, passenger and freight travel on the roads will face significantly more congestion and much longer travel delays. The industries that rely on the time-sensitive movement of goods and materials could have difficulties adapting to a less responsive freight-transportation network and may subsequently become less competitive in the marketplace.

Figure 4.9
Projected Concentration of Trucks on Routes on the National Highway System in 2035



SOURCE: *Freight Facts and Figures 2008* (FHWA, Office of Freight Management and Operations, 2008, Figure 3.9).

NOTE: VCR = volume/service flow ratio.

RAND MG883-4.9

In addition to the demand placed on the roads, other factors will influence the future capacity of roads and highways. IT improvements, by coordinating return trips for trucks after freight is delivered or utilizing real-time knowledge of road congestion for rerouting trucks,⁴ can increase capacity by decreasing wasteful movements of empty trucks. Of course, additional economic contractions or a deeper

⁴ Of course, many trucks carry specialized commodities (such as chemicals, sand and gravel, and food products) that do not move in both directions and that limit the ability to reduce empty-return trips. The DOT Freight Analysis Framework assumes that, depending on the commodity type and type of truck, empty trucks constitute 10 to 50 percent of trips, on average.

recession could greatly reduce the demand for goods movement on the highways. Fuel-price increases can drive some supply-chain users to shift more of their goods movements to rail. Reduced packaging of products can also reduce the freight demand. A shift away from the primary points of entry of the West Coast ports to other points of entry into the United States could redistribute freight movement and moderate congestion in certain geographical regions or across the entire network.

Rail-Freight Capacity

Rail-freight capacity is dictated by a combination of factors:

- the amount of railroad track and rolling stock
- the type and number of locomotives
- the topographical grade of a region that utilizes rail
- freight-car rail-size and weight limits
- the operational-speed ranges
- the types of signal and control systems used
- operating strategies of the railroad companies.

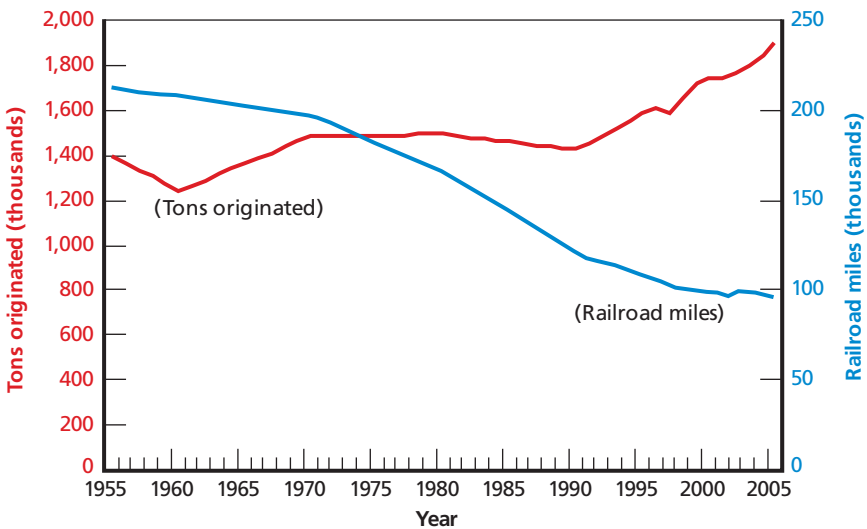
Because so many factors influence the capacity of rail freight, it is difficult to estimate a true capacity value for the system. A generalized approach considers four interrelated factors that determine railroad capacity: infrastructure, motive power, operating strategies, and crews (McClellan, 2006). These general components of capacity can be used to weigh the benefits and capacity gains of operational changes and short-term investments versus medium- and long-term infrastructure investments.

The U.S. physical rail network has contracted from its peak of approximately 254,000 miles in 1916 to 141,000 miles today (Stover, 1997; AAR, 2009). Several changes have influenced the decline in the physical infrastructure of the rail network. The development of the Interstate Highway System, passenger air travel, and the reduction of the U.S. manufacturing base have all decreased the country's reliance on rail. In addition, several technological and operational advances have improved the productivity of the rail network and increased the effec-

tive capacity of the network. Figure 4.10 illustrates how the rail network has decreased in overall physical track-miles yet increased in the tons moved on the network. These changes reflect the structural reduction of the physical network, the technology and operational advances made in the past 50 years, and increasing demand from a growing economy.

A recent study by Cambridge Systematics (2007) for AAR examined capacity and rail utilization of the major corridors of the rail freight system. Figure 4.11 displays segments that were below capacity (green), near capacity (yellow), at capacity (orange), and above capacity (red) in 2007. According to the report's authors, when rail corridors operate below capacity, or at less than 70 percent of capacity utilization, the flow of trains can accommodate and be relatively unaffected by changes in capacity due to maintenance, equipment failures, and weather delays. If the corridors are operating near capacity, or from 70- to 80-percent utilization, delays from maintenance become more pronounced. When corridors operate at or above their capacity,

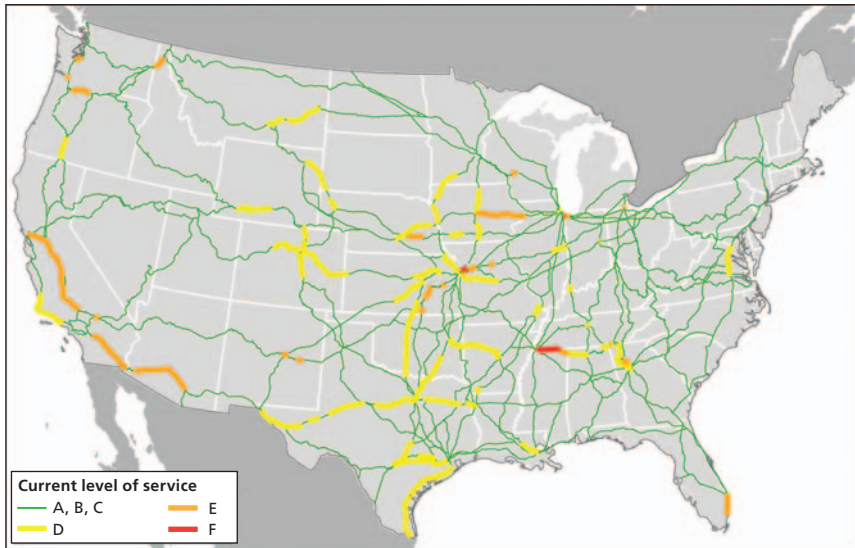
Figure 4.10
Railroad Network Miles and Railroad Tons Originated, 1955–2005



SOURCE: Weatherford and Willis (2008, Figure 2.2).

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Figure 4.11
Utilization of Major Freight Corridors in the Railroad Network



SOURCE: Cambridge Systematics (2007, p. 4-10, Figure 4.4). Used with permission.

RAND MG883-4.11

more than 80 percent to beyond 100 percent of the capacity utilization, the flow of trains can become uncertain, and service delays and congestion-related delays may be significant and unpredictable. The delays and uncertainty negatively affect businesses that rely on just-in-time shipments and predictable rail performance.

The 2007 Cambridge Systematics study also estimated that 88 percent of the rail network is currently operating below capacity, 9 percent is near its capacity limit, and approximately 3 percent is either at or above its capacity limit. However, viewing the network capacity by mileage may be misleading. Because rail capacity is a function of several factors and includes a highly integrated set of intersection points, or nodes, and linkages between nodes, or arcs, the true network capacity may be higher or lower than defined by track capacity.

For example, several rail intersections and terminal transfer locations may be near or at capacity. They include critical shipping locations, intersections, and transfer hubs, such as Los Angeles and

Chicago, that require large amounts of capacity to receive, ship, and transfer goods between intermodal facilities and rail terminals. If the movement of goods operates at or near capacity in these locations, large sections of the network may be affected by delays, effectively decreasing the overall capacity and performance of the U.S. freight transportation system.

There are several historical illustrations of how relatively minor perturbations or changes in network capacity can lead to large time delays and network-capacity constraints. Examples include labor strikes at major ports (Gooley and Cooke, 2002); corporate mergers and consolidation of railroad operators (Fulmer, 1998); and rail-line reprioritization and rerouting (Phillips, 2004).

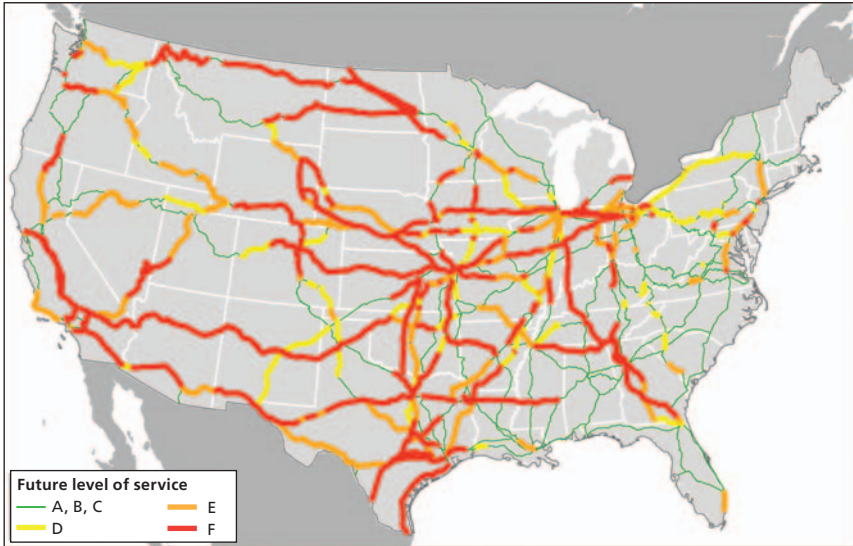
Such disturbances show that the current transportation network may not be sufficiently robust to adequately support events that limit capacity for even short periods of time. Policymakers need to address ways to improve the robustness of the existing rail network to economic growth, national disasters, and terrorist events.

Figure 4.12 illustrates the challenge that projected economic growth could have on the rail network. Using freight-demand estimates provided by the DOT, the Cambridge Systematics study concluded that, given existing capacity levels, approximately 55 percent of the national rail network would be near capacity, at capacity, or above the capacity limit by 2035.⁵ If the rail network demand were to grow at these levels, users of the network would observe long and highly variable transportation delays through many corridors in the network. Industries with time-sensitive requirements would be likely to shift a larger percentage of their goods to truck shipment alone, which would likely create further congestion in the highway network, increase inventory held by businesses at various stages within the supply chain, and increase transportation-related costs to the end customer.

The traditional funding source for building, upgrading, and maintaining rail capacity is the operating budgets of rail companies. Rail companies have much higher fixed cost structures and must invest

⁵ The DOT estimates do not reflect the economic downturn of 2008.

Figure 4.12
Projected Utilization of Major Freight Corridors in 2035



SOURCE: Cambridge Systematics (2007, p. 5-5, Figure 5.4). Used with permission.

RAND MG883-4.12

more heavily in infrastructure than other industries.⁶ Although the rail industry should be expected to have higher capital expenditures as a percentage of revenue, large-scale infrastructure improvements require massive investment and may be considered financially risky to a specific company or the collective industry. Therefore, rail companies will seek first to improve capacity through efficiency gains.

One such example is positive train control (PTC), which allows more trains to travel safely on the existing network. Such an efficiency improvement allows rail companies to increase network capacity at a lesser investment cost than laying new track. As a general rule, rail companies consider increasing physical tracks as a last option because it requires significant investment.

⁶ Capital expenditure as a proportion of revenue is about 17 percent for class I rail versus 3 percent on average in manufacturing industries (AAR, 2008).

Several recent examples of infrastructure projects have relied on a combination of rail companies; private businesses; and local, state, and federal organizations for funding large-scale infrastructure projects. These initiatives are known as public-private partnerships (PPPs) and have been an effective way for groups of stakeholders to finance projects that may not be possible for any one stakeholder to fund. Examples of successful PPPs include the Alameda Corridor Transportation Authority (ACTA Web site, n.d.) and CREATE programs (FHWA, Illinois Division Office, 2005).

The Alameda Corridor was created to allow cargo to be moved efficiently through the San Pedro Bay area from the Los Angeles and Long Beach ports to the transcontinental rail network near downtown Los Angeles. CREATE, which is in the implementation phase, is working to improve and facilitate the efficient flow of freight through the greater Chicago region in five major corridors. Although these projects required large amounts of funding, \$2.4 billion and \$1.5 billion, respectively, the PPP model was effective because there were many mutual benefits to stakeholders. These projects have been considered successful in allowing more-efficient rail movements; reducing automobile traffic congestion and delays; reducing air and noise pollution from idling automobiles and slow-moving trains in surrounding communities; and promoting economic development and job creation in their respective regions. Future projects include the Alameda Corridor East (ACTA Web site, n.d.) and the Heartland Corridor (Norfolk to Cleveland to Chicago) being planned to increase rail capacity and efficiency in specific cities and regions (Norfolk Southern, 2008).

The AAR (2008) estimates that the infrastructure improvements required to meet the demand of 2035 will cost \$148 billion (2007 dollars): \$135 billion for class I freight infrastructure, and \$13 billion for regional freight and short-line railroads. These improvements would include upgrades to mainline tracks and signal-control systems; upgrades to rail branch lines and bridges; and expansion to carload terminals, intermodal yards, international gateways, and service and support facilities. If these investments were made and the growth of rail-freight demand were as predicted, the study estimates that less than 3 percent of the total mileage would be considered near capac-

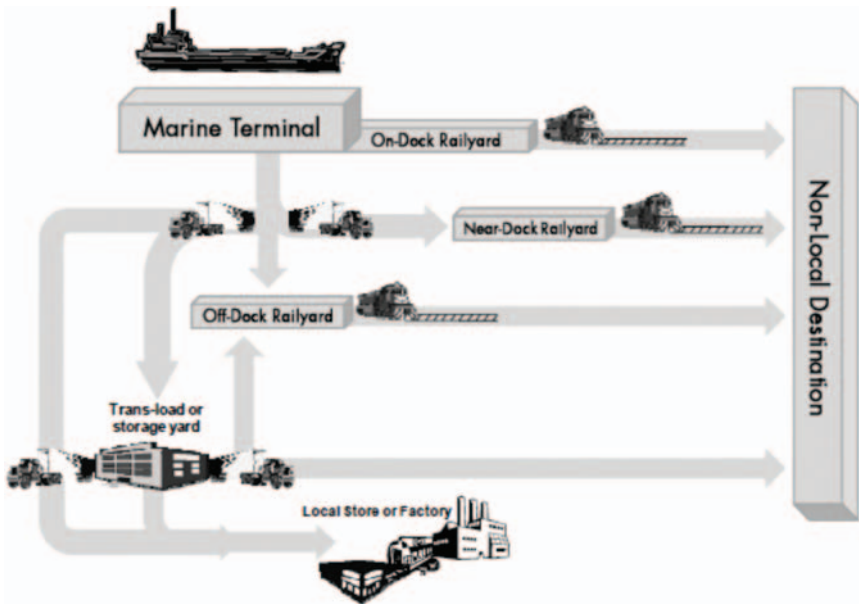
ity, at capacity, or above capacity. We note that a rail-freight system that is not significantly capacity-limited is important to a reduced reliance on trucking to move freight throughout the network, decrease congestion on many of the highways and interstates, and potentially reduce the total cost of transportation for many businesses.

The AAR (2008) study concluded that class I railroads could generate \$96 billion of the \$135 billion over the estimated time period and recommended that the remaining \$39 billion shortfall come from railroad investment tax incentives, PPPs, or other sources. Some studies, including a recent RAND study (Weatherford and Willis, 2008), have noted that key railroad infrastructure studies, such as the AAR reports we have quoted, have been sponsored by trade organizations representing railroad-interested parties. The reliance on trade organizations to produce the railroad studies may undermine the public's and policymakers' confidence in the real requirement for public funds. If public funds are used to support rail-infrastructure growth, the rail companies may be subject to higher levels of government oversight and may have to increase their level of accountability to the public.

Port Capacity

The *capacity of a port* is a function of several physical factors, as well as the coordination of policies among stakeholders. Some of the most important physical factors for this capacity are local roads, terminal space, local rail, labor or longshore efficiency, local trucks, berthing space, available land for movement and storage of containers, longshore costs, longshore capacity, and on-dock rail (Maloni and Jackson, 2005a). Waterside capacity, such as pilotage; tug and towing services; and ocean transportation intermediaries (OTIs), which include freight forwarders and customs brokers, contribute to capacity (Maloni and Jackson, 2005b). More importantly, the capacity of a port is dependent on its ability to flow freight onto the off-port road and rail infrastructure. Figure 4.13 depicts the alternative ways in which freight is moved from ports.

Figure 4.13
Diagram of Port Operations



SOURCE: Port of Long Beach. Used with permission.

RAND MG883-4.13

Total port throughput capacity cannot be increased without synchronized, joint planning among the port authorities, longshore labor, terminal operators, railroads, drayage carriers, and government (Maloni and Jackson, 2005a, b). IT often plays an important role in enabling and supporting coordination, particularly with respect to terminal operations.

Other policies and phenomena may affect port capacity, such as security regulations, terrorism-prevention activity (for example, the screening of containers), military deployments, labor strikes, weather and natural disasters, and seasonality of demand (Maloni and Jackson, 2005b). The economic consequences of a disruption to the flow of containerized freight at a port could be very large. The CBO (Arnold et al., 2006) estimated that a one-week shutdown of LA/LB would cost the U.S. economy \$65 million to \$150 million per day, and that a three-year shutdown would cost \$45 billion to \$70 billion per year.

Port-expansion plans include measures to increase efficiency through increased use of technology, gate hours, labor efficiency, terminal space, berth space, and channel depth; more terminals; expanded use of short-sea or barge feeders; and development or expansion of inland ports comprising rail and truck facilities (Maloni and Jackson, 2005b). Table 4.1 summarizes some capacity-expansion projects that are under way at several of the major ports.

Reducing Local Effects with Operational Adjustments

Spreading port activity across the time of day can improve flow and decrease congestion effects. The I-710 Freeway, which serves the Port of Long Beach, has annual average daily truck traffic of 27,500 (11 percent of all vehicles). Because much of this traffic occurs during peak passenger periods, it has been associated with approximately 1.4 million hours of delay annually.

In July 2005, LA/LB instituted a program called PierPASS (BST Associates, 2008). Since then, all marine terminals in LA/LB have offered off-peak shifts on nights and weekends. As an incentive to move traffic to off-peak hours, a traffic-mitigation fee is required for cargo movement through the ports during peak daytime hours: \$50 for a TEU or \$100 for a 40-foot container. This cost is used to help offset the additional costs of operators because the terminals are left open during off-peak hours. Figure 4.14 shows the growth in the use of the off-peak-hours program. The expectation is that the program will have a significant effect on reducing truck traffic and pollution during peak daytime traffic hours and alleviate terminal gate congestion.

Port and Terminal Productivity Measures

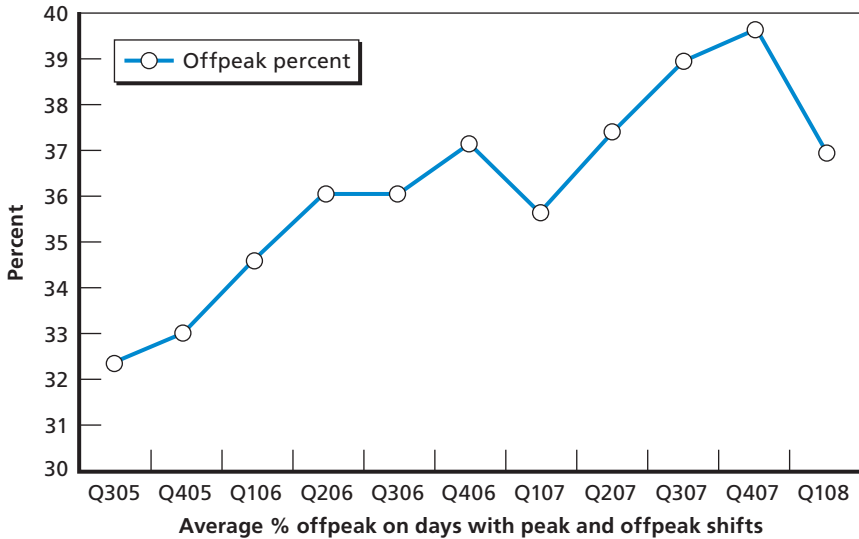
Port productivity is a function of how quickly containers can be handled and moved off the site to their next destination while efficiently using available ground space (Le-Griffin and Murphy, 2006). *Container-handling efficiency* is determined by the number and movement rate of quayside cranes, the use of yard equipment, the ground-space utilization of the yard, and the productivity of the labor involved in all movement tasks. Ground-space utilization and container accessibility

Table 4.1
Current Port Capacity–Expansion Projects

- The Port of New York/New Jersey is spending \$1.7 billion to reconfigure existing terminals, deepen harbor channels and berths, and improve inland access by rail and barge.
- The Port of Houston is investing \$1.4 billion in the Bayport Container Terminal, which will have a capacity to move to 2.3 million TEU per year.
- The Port of Charleston is investing \$792.7 million in a 280-acre container terminal on the former Charleston Naval Complex, which will boost capacity by 1.4 million TEUs; make capital improvements, deepen the harbor, and maintain and improve the Arthur Ravenel Jr. Bridge.
- The Port of Seattle is spending \$368 million in terminal expansions, pierside rail-spur development, and harbor deepening.
- The Port of Tacoma is spending \$404 million to increase container-movement space, increase the efficiency and capacity of railyards, and complete cleanup projects of port-owned property.
- The Port of New Orleans is investing \$1 billion to complete an additional container terminal, which will increase capacity to 1.3 million TEU per year. This investment includes dockside cold storage, additional building and shed construction, and additional container cranes.
- The Port of Savannah is investing \$1.2 billion in operational-efficiency improvements, which will include the acquisition of 25 post-panamax (*panamax* refers to the largest vessel size that can pass through the Panama Canal) container cranes and 86 gantry cranes, and harbor dredging to deepen the waterway, which will result in increasing capacity to 6 million TEU per year by 2018.
- The ports that constitute the Hampton Roads area are investing \$291 million in harbor deepening and construction of road and rail connections to a new marine terminal.
- The Port of Miami is spending \$172 million in harbor deepening and maintenance dredging.
- The Port of Oakland is spending \$16 million on a near-dock intermodal terminal, harbor deepening to 50 feet, and the conversion of Army lands turned over to the port as part of the Base Realignment and Closure (BRAC) to a 425-acre cargo terminal (Port of Oakland, 2005).

SOURCE: The Web site of each port was examined to identify planned port capacity–expansion efforts.

Figure 4.14
Off-Peak Usage at the Ports of Long Beach and Los Angeles Since the Inception of the PierPASS Program in July 2005



SOURCE: PierPASS Web site (2008).

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are inversely related (Le-Griffin and Murphy, 2006). Transshipment ports, such as Hong Kong and Singapore, differ from origin-destination ports, such as Long Beach, Tacoma, and Houston. Transshipment ports depend much more on the efficiency of waterside operations, such as berths and quayside container cranes, whereas origin-destination ports depend much more on landside operations, such as terminal gates and marshalling yards (Le-Griffin and Murphy, 2006; Dowd and Leschine, 1990). *Berth productivity* is often measured as the number of container-vessel shifts worked per year per berth; this metric is a simple statement of how many ships are unloaded at each berth space per year and is commonly out of the direct control of the port or labor. *Labor-productivity* measures often include the number of cargo or container moves per man-hour; this is a very simple measure and may not account for the effects of the capital equipment driving

or limiting the number of moves at a particular location.⁷ A common metric for *overall container-yard efficiency* is TEUs per year per gross acre; this metric evaluates the efficiency of both operations (throughput speed) and land use. A measure of *transfer operations* (ship to yard and yard to truck or rail) is the number of moves per crane or longshoreman gang-hours. Gate metrics tend to evaluate truck-turnaround time or the utilization of lanes, such as containers per hour per lane. Table 4.2 compares some major container ports in terms of several throughput measures.⁸

Another indicator of relative productivity is that European and some Asian terminals operate lift cranes at a rate of 30–35 lifts per hour versus an average of 25 lifts per hour in the United States (National Research Council, Committee on Productivity of Marine Terminals, Marine Board, 1986). The Committee on Productivity of Marine Terminals concluded that “an important factor influencing productivity

⁷ The international transshipment ports may count the container moves “once” across the marine terminal wharf and onto the terminal and then a “second count” across the marine terminal wharf and onto a coastal or feeder vessel or Short Sea Shipping vessel. Many of these transshipment ports use a “midstream transfer” process, whereby tow vessels exchange container transshipment cargo midstream. This transshipment process overseas may result in transshipment cargo representing a majority of all cargo handled. Most North American ports count only the throughput of a container “once” as it transitions the marine terminal wharf. Thus, the North American port transshipment process may be recorded with a much lower level or proportion of moves.

⁸ The authors (Le-Griffin and Murphy, 2006, p. 8) note,

[c]are should be taken, however, when these aggregate statistics are used to quantitatively measure the performance of different terminals. While the numbers may indicate that a port is underperforming in a certain aspect relative to other ports, a hasty effort to improve the productivity measure of a particular operational element could unintentionally undermine the overall economic efficiency of the entire container handling system. Taking the land utilization rate as an example, a lower number is often interpreted to be less efficient in a comparison chart. The real meaning of this rate, however, will depend on the economic circumstances of a particular terminal. One would expect “lower” land utilization rates in areas where land is relatively cheap and labor expensive. As such, these rates may be of limited value in making straight comparisons of productivity. The ultimate significance of these comparative statistics is that they allow us to understand the operational characteristics of the ports of Los Angeles and Long Beach, as well as the rationale supporting the current productivity achieved by their operations.

Table 4.2
Productivity Measures of Selected Leading Container Ports

Port/Terminal	Throughput (TEUs, 2004)	Throughput Density (TEUs/acre)	Throughput/ Crane (TEUs)	Throughput/ Quay Length (TEUs/ft)
Los Angeles, Calif.	7,321,440	4,342	106,108	229
Long Beach, Calif.	5,779,852	4,501	84,998	210
Kwai Tsing, H.K.	13,425,000	19,070	156,105	480
Singapore	20,600,000	24,582	174,576	523
Rotterdam	8,300,000	7,168	89,247	251
Antwerp	6,063,746	5,041	97,802	196
Hamburg	7,321,479	7,285	126,232	304
Tacoma, Wash.	1,798,000	3,519	81,727	190
Klang, Malaysia	5,243,593	13,549	119,173	339
Barbour's Cut Terminal, Houston, Tex.	1,440,478	5,762	120,040	240

SOURCE: Le-Griffin and Murphy (2006). Used with permission.

is the state of labor-management relations,” and “the most promising area for improving marine terminal productivity in the United States lies with better employment of people” (Waterfront Coalition, 2005).

Ultimately, capacity is not simply about infrastructure. It depends on the efficiency of operations, the pattern of demand, the productivity of the individual modes and the transition between modes, and the objectives of the users of the system.

Overarching Issues for Improving Freight Transportation and Implications for Policy

Identifying the Key Issues

This monograph began with a focus on identifying the key issues in improving the capacity of the U.S. national and international freight-transportation systems. Most projections indicated that capacities of ports, highways, and the railroads were nearing their limits in key urban areas and corridors and would soon be constraining factors for goods movement, consequently impeding U.S. economic growth. Although the current severe economic contraction has slowed growth projections and made capacity concerns less immediate, even the revised growth continues to imply large future demands for freight transportation.¹

Furthermore, enhancement of the nation's transportation infrastructure has been increasingly promoted as an important forward-looking element of an economic stimulus package. The previous chapters provided a quantitative overview of U.S. freight transportation, its projected growth, and the various determinants of the capacity of that system. In this chapter, we suggest four freight-transportation and freight-infrastructure issues that appear to be the most significant as the nation moves forward with transportation-infrastructure developments to foster future economic growth. Their significance is drawn from our review of data about freight-transportation growth and factors underlying system capacity, discussions with stakeholders, our study of

¹ A revised CBO estimate of a 2.4-percent long-term growth rate of the U.S. GDP implies that doubling of truck transportation occurs in 30 years instead of 25 (FHWA, FAF Web page, 2009).

proposals for improvements, and our understanding of the potential effects on measures of freight transportation. Such measures include system capacity, system reliability, costs to users (including the need for pipeline and uncertainty inventory), costs of improvements, vulnerability (to disruption from nature, labor, terrorism), resilience (ability to recover from disruption), adaptability (to future economic development), and social effects (safety, congestion, accessibility, energy use, harmful emissions, etc.).

Four Key Issues for the U.S. Freight-Transportation System and Related Policy Implications

Issue 1: Increasing the Capacity of the U.S. National and International Freight Systems Through Operational Improvements and *Selective* Infrastructure Enhancement

Rationale. Long-range projections of highway, rail, and international flows of freight indicate the need for additional capacity at all parts of the freight-transportation network. However, enhancing freight-transportation capacity does not necessarily mean adding and upgrading infrastructure, such as highway lanes, ports, and rail track everywhere, nor even at all apparent bottlenecks. Rather, it should be done by utilizing all the tools at hand, including regulations, pricing, and technology, and *selective* infrastructure improvements to increase the overall productivity and capacity of the system. As we noted, the important advantages of operational enhancements to capacity are that they can often be implemented in the near term (in contrast to the long lead time of infrastructure-construction projects) and that the increased productivity of the resulting system reduces costs and often reduces energy use and emissions.

The interaction between demand and capacity can be complex. Transportation users adapt to constraints in various ways—shifting modes, shifting demands in time and space, and changing prices. At any point in time, only some parts of the system will be constrained, permitting other parts to substitute, if feasible. Capacity is also a non-linear function of demand, in which a little more flow on a congested

link can force a tipping point in which the overall flow is dramatically reduced. The result of interactions between demand and capacity do not always mean a stoppage of flow, but such interactions do increase costs, add uncertainty, cause delays, and decrease demand. Thus, any study of the capacity of the freight system requires a corresponding study of the pattern and flexibility of the demands on the system.

Most of the users of the U.S. freight-transportation system whom we interviewed, as well as many of the operators, emphasized the importance of *operational* improvements (i.e., in how the system is used) that, even in the near term, could provide substantial capacity increases. Such improvements include changed labor rules to allow or encourage 24/7 operations, increased use of IT to improve routing and avoid congestion, and incentives to increase utilization of unused capacity in off-peak periods. Some of these operational improvements may require selected infrastructure improvements, such as specialized truck lanes to reduce competition with passenger traffic and rule changes to permit larger trucks or the construction of an IT-based freight “infostructure” to facilitate the movement of freight between modes.

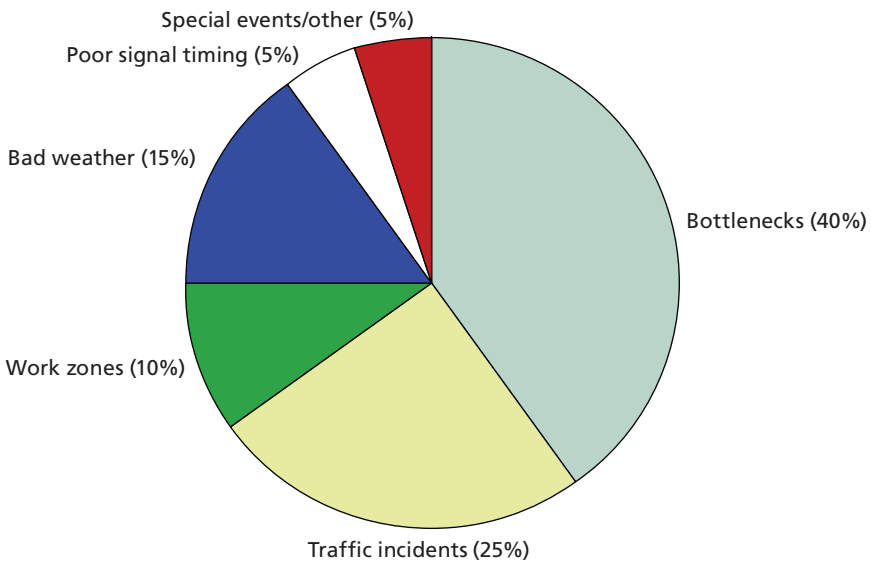
In Chapter Four, we separately examined capacity limitations associated with the freight movement on highways, on the rail system, and through ports and their environs. We repeat some of that discussion here, along with potential mitigation measures.

Mitigating Highway Freight Congestion. The most apparent indicator of limited highway capacity is traffic congestion. Urban highway congestion is a very significant factor in freight delay and shipping cost now. Trucks on highways carry about 75 percent of the nation’s freight by ton and about 90 percent by value, and cover 40 percent in ton-miles (BTS, 2007b). A 2005 study of freight bottlenecks by Cambridge Systematics and the Batelle Memorial Institute estimated that the delays caused by various types of bottlenecks in the United States amounted to nearly 250 million hours of truck delay, creating a direct cost to truckers of approximately \$8 billion. The full costs of such congestion may be considerably higher: Emissions are greater because of the congestion, fuel use increases, and accidents are more likely in congestion. In addition, the expectation of congestion leads to scheduling extra time for expected delays, use of additional trucks and drivers to

meet schedules, and greater holding of inventory to deal with uncertain arrivals. Projections of highway freight growth are that it will increase by 75 percent by 2020, and projections of congestion growth are that more than 40 percent of the NHS will be congested during peak periods (see Chapter Four). The concurrent effect of passenger delay in such congestion may be such that even more significant issues arise for trucking, including limitations on truck use of congested highways during peak periods.²

Highway congestion has other causes as well, as indicated in Figure 5.1. The time and location of many of these causes cannot be

Figure 5.1
Other Sources of Congestion



SOURCE: Cambridge Systematics, with Texas Transportation Institute (2004, p. ES-6, Figure ES.4).

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² Generally, truckers would prefer to avoid peak congestion periods anyway, but delivery schedules and delivery hours often do not permit doing so. Furthermore, peak congestion periods may extend for much of the day in the future.

predicted, but that does not mean that there are no mitigation measures. Reducing bottlenecks will reduce some causes (e.g., fewer bottleneck-related accidents), and there are operational mitigation measures, such as incident-response teams, that can reduce still others.

Four major approaches can be taken to reduce road congestion: adding physical capacity by adding traffic lanes or permitting larger trucks, spreading demand across time and space, providing incentives to shift mode to rail or waterway, and reducing overall demand (e.g., reducing packaging). Of course, these approaches can be implemented through a variety of mechanisms, including user fees, regulations, and new information technology. A recent RAND report describes the difficulty of expanding the highway infrastructure to resolve the congestion problem in a heavily populated urban region such as Los Angeles, because the additional capacity attracts more users, eventually re-creating the congestion that existed originally (Sorensen et al., 2008a).

One lasting alternative that was suggested is to spread the demand by using congestion pricing for peak periods. Other alternatives that are primarily operational include designating more lanes as high-occupancy vehicle lanes (i.e., carpool lanes), signal timing and priority controls, limits on curbside parking on major corridors, incident-response teams, and additional public-transit capacity to remove people from automobiles. Most of these alternatives would be aimed at passenger vehicles, the dominant cause of the congestion; however, they would likely provide important benefits for freight transportation as well.³

Another alternative is to increase the capacity for trucks by building special truck-only lanes. One advantage of such lanes is that rules limiting the size of trucks can be relaxed, dramatically increasing the capacity. Allowing triple-trailer trucks, for instance, automatically increases the capacity by 50 percent. Such rule changes would, of

³ In our interviews, some interviewees questioned whether freight trucking would respond to congestion pricing in the same way as passenger vehicles because of the necessity to meet delivery schedules and the possible lack of suitable alternative routes for trucks. However, reducing auto traffic during peak periods would benefit all.

course, be possible only on truck lanes and routes that do not need to rejoin automobile traffic lanes with truck-size limitations.

Other operational measures include changing the freight-transportation demand. One example of an approach to spreading the demand in time is PierPASS, instituted for drayage trucks at the Port of Los Angeles. As described in Chapter Four, this program encourages the shift of trucking activity to off-peak traffic periods by charging more per container for terminal-gate access during peak rush-hour periods, somewhat mitigating the addition of port-related traffic to the local highway system. Some operational tactics can reduce the overall goods volume on trucks, including reduced packaging and mode shift. One company we interviewed has made it a goal to reduce the amount of packing materials by 5 percent, reducing the volume and weight and permitting more goods on each truck. The primary issue with this approach is the possibility of increased damage. Another approach, mentioned in our interviews and apparently being adopted by some producers, is to ship more-concentrated, water-based products.

Moving more goods by rail instead of truck could reduce the freight demands on the highway system. In addition to reducing highway congestion, the social effects of rail—accidents, air pollution, greenhouse-gas emissions, and noise—have been calculated to be approximately 25 percent those of highway trucking per ton-mile (Forkenbrock, 2001; Weatherford and Willis, 2008). The primary barrier to such a mode shift is the increased time and uncertainty of rail transport. Because trucks must often deliver goods for rail transport to rail terminals and ultimately make the final delivery at the destination, using rail for short distances takes longer and requires more delay than direct truck delivery. As a rule of thumb, it is not as efficient to use rail to transport goods that have customers closer than 350 to 500 miles.⁴

Factors that can increase the shift of goods from road to truck include improved intermodal facilities (speeding the transition between rail and truck); short-haul rail that moves containers directly from ports to inland centers, reducing truck movements on port-connector high-

⁴ This, of course, depends on the commodity carried, its value, and the location of rail terminals.

ways; and IT-based tracking systems that help to control and speed the movement of goods between modes. It may also be possible to develop short-sea solutions for selected high-use ports that take advantage of less-congested waterside transfer and move the freight to nearby ports with less urban highway congestion (Santa Maria Group, 2006).

Enhancing the IT infrastructure associated with freight could make the movement of freight more efficient in a number of ways, including using radio-frequency identifier (RFID) tracking to avoid losses, and coordinate and speed movement through mode changes; deploying electronic container-truck reservation systems for use with marine container-terminal operations; identifying in real-time traffic breaks and routing for congestion avoidance; and coordinating pickups and deliveries to reduce empty return trips. One option described for LA/LB is the Virtual Container Yard. This is basically a Web-based information system that allows trucks handling containers from the ports to find an empty or full container to bring back to the port (International Asset Systems, n.d.).

Mitigating Rail Freight Congestion. The capacity of the rail system is determined by a complex combination of tracks, individual train capacity, limitations of bridges and tunnels, maintenance requirements, speed, and train-control systems. As shown earlier, the long-distance class I rail systems have generally decreased their track-miles (mostly by removing service on low-use spur tracks) while increasing their productive use of the remaining track, leading to an overall increase in ton-miles for freight hauled on the rail system. An AAR analysis of current and future levels of service of the U.S. class I railway system indicates that, at present, 88 percent of the primary corridor system is operating below capacity, 12 percent at near capacity, and less than 1 percent above capacity (AAR, 2009). According to the report, *near capacity* means that there is heavy train flow but enough capacity to accommodate maintenance and recover from incidents. *Above capacity* implies “unstable flows [and] service breakdowns.” The report goes on to project the effect of 88 percent more tonnage handled by

rail in 2035.⁵ In this case, without improvements to increase capacity, the projection is that only 45 percent will be operating below capacity, with 25 percent operating near or at capacity, and 30 percent operating above capacity.

Freight rail operations in urban areas are subject to and the cause of additional congestion, from delays in automobile movement at railroad grade crossings, accidents at such crossings, competition between freight and passenger rails sharing the same tracks, and competition between rail freight companies and ownership of rights-of-way at which tracks merge and cross in key freight gateway cities.

The AAR report estimates that mitigation (basically to achieve the same uncongested level of freight rail service in 2035 as now) will require approximately \$148 billion in infrastructure improvements. These infrastructure improvements include line-haul tracks, major bridges, tunnels and clearance, branch-line upgrades, terminal expansion, and additional service facilities.

We note generally that many of the capacity enhancements do not necessarily involve adding track but do involve other forms of infrastructure, such as IT-based control systems, and may require track upgrades. Centralized traffic control (CTC) enhances the capacity through an IT-based central dispatching system that permits more trains to utilize a given set of tracks than the older forms of autonomous control, such as automatic block signaling. The capacity increase attributed to this is 50 percent to nearly 100 percent, depending on the number of tracks and variation in types of trains utilizing the tracks (AAR, 2009; Weatherford and Willis, 2008). Other increases in capacity can be obtained by longer trains (may require more siding track), heavier trains (may require upgraded tracks and bridges), more double-stacked container trains (may require tunnel upgrades on some corridors), and faster trains (may also require some track upgrades).

Operational strategies—including assembling *unit trains*, in which every car goes to the same destination from the same origin, thereby eliminating the multiple stops and rail-car switching common

⁵ The 88-percent increase for rail is consistent with the 100-percent increase in freight-tons moved that was projected for the freight system as a whole.

to heterogeneous loads—can provide additional rail capacity without increasing infrastructure.

As discussed in Chapter Four, CREATE is a good illustration of an approach to reducing urban rail and rail-induced highway congestion (FHWA, Illinois Division Office, 2005). A severe snowstorm in the winter of 1998–1999 paralyzed rail freight service in Chicago, and the associated freight-rail congestion severely stalled the commuter-rail system. One response was the formation of a PPP to study the situation. A prominent finding was that freight and passenger rail lines interfered severely with each other. Freight rail came to a near standstill during commuter rush hours, and commuter service was seriously delayed, allowing little capacity for desired increases in the commuter transit system. The CREATE program, notable for its cooperation between rail companies and levels of government, defined and set up a system of private, local, state, and federal funding to create corridors shared by multiple rail freight companies, to separate passenger and freight rail (*flyovers*), and to remove many highway–rail grade crossings.

Mitigating Port Congestion. One of the major concerns in international freight movement has been the projected growth in shipments through U.S. ports. Between 1997 and 2006, container shipments through the major U.S. ports increased at an average of 7- to 8-percent annual growth rate (Waterfront Coalition, 2005). Projecting this figure to a rate of growth in the future indicates the need for an ability to handle four or more times as many containers within 20 years (National Surface Transportation Policy and Revenue Study Commission, 2008). The recent economic contraction has made such projections moot for the more immediate period, and, in fact, the Port of Los Angeles recently curtailed terminal operations on weekends because of the drop-off in demand.⁶ At this point, it is unclear how the long-term projection will be affected by the severe worldwide recession.

In addition to a near-term reduction in container moves, major business transformations that involve a reduction in offshore manufacturing could occur, leading to considerably less long-term growth

⁶ See “Frozen Ports in Long Beach/Singapore Mean Bleak 2010 (Update 1),” *Bloomberg News*, December 23, 2008.

or no growth. However, the reversal of oil-price increases, which were increasing supply-chain costs, may have removed some of the incentive to back away from Asian manufacturing.

Without attempting to be predictive of the uncertain long-term trends in port demands, we can still make some conclusions about port capacity:

First, as shown in the preceding chapter, it appears that U.S. ports themselves have additional capacity. With alternative labor agreements, port operations could be expanded to 24/7 from the current daytime or overtime rules. Container moves per hour at U.S. ports might be increased to match those of some foreign ports, and containers moved per acre of port per year, an alternative measure of port productivity, are below those of some high-performing foreign ports, such as Singapore, Hong Kong, and Shanghai.⁷ Thus, increasing port productivity might accommodate previously projected growth (7 to 8 percent) for 10 to 15 years and a slower growth rate for substantially longer. The real problem related to port growth is the capacity of the connecting infrastructure (the highways and rail system that connect ports to the hinterland) and the effects on the urban areas surrounding the ports.

The congestion of port connections, particularly the highway system, must be mitigated. Such connections lie largely in urban areas, and the highways are generally congested already. In addition to the aforementioned approaches to reducing highway congestion affecting trucks, a number of approaches can offer some relief of port-area congestion, including the following:

- Institute incentives for trucks to move goods from ports during off-peak hours. The PierPASS at the Port of Los Angeles is an example of using container fees as an incentive.
- Utilize short-sea shipping (waterside transshipment) to nearby ports to move the landside (trucking and rail) load from the congested port.

⁷ Comparisons with other ports can provide some indicators of relative performance and potential improvements, but, because of differences in infrastructure and types of operations at the ports, they are, of course, imperfect measures.

- Utilize short-haul rail to reduce the trucking load in the vicinity of the port.
- Charge differential container fees at high-volume ports to encourage the spread of shipments to alternative ports. These fees would not be set high enough to cause all shipping to move but would encourage some leveling of the use of ports and could be used to pay for additional infrastructure to mitigate congestion.
- Construct special truck-only lanes from ports to distribution and consolidation centers. These truck lanes could be financed by the aforementioned container fees and, with rules permitting larger or heavier trucks than the normal highway system, would dramatically increase freight-trucking capacity.

Elements of a robust solution to improving freight capacity include the following:

- Generally, passenger traffic is a significant cause of road freight congestion in urban areas, so reducing the congestion will require tactics to reduce passenger traffic on congested highways, including congestion pricing and increased urban mass transit.
- Mitigate road freight congestion with operational tactics, to attempt to spread transportation demand in time and location (the previously described PierPASS, for example), as well as reduce the overall demand (providing alternative modes and reduced packaging are two such alternatives).
- Decrease the intersection and interference of freight and passenger traffic on urban rail and highways (Alameda Corridor and CREATE are examples).
- Provide more opportunities for mode shift from road to rail or waterway (more streamlined and transparent intermodal connections; for example, hour-by-hour tracking of cargo, and tracking of an individual package as it moves from location to location and across modes of transportation).
- Develop an IT-based “infostructure” to facilitate freight movements across modes and increase the efficiency of the system.

- Plan to increase rail-system capacity with a mix of operational improvements and selected infrastructure developments.
- Develop port-connector strategies that reduce the congestion and other negative social effects of moving goods to and from ports in urban areas.

Issue 2: Creating an Adaptable, Less Vulnerable, and More Resilient Freight-Transportation System

Rationale. The ability of the U.S. freight-transportation system to adapt to changes in demand is important for dealing with the unknown future directions of the U.S. and world economies, as well as for responding to unpredictable disruptions. Currently, as we have shown in Chapter Four, most international freight moves through a small number of U.S. ports (about 75 percent through just two major port complexes and 90 percent through ten ports). (History has demonstrated the vulnerability of this configuration. The CBO has estimated the cost of a 10-day shutdown of the POLA/LB to be \$65 million to \$150 million per day, and a 3-year shutdown to be \$45 billion to \$70 billion per year, respectively.) Such closures could also occur as the result of terrorist actions or earthquakes. Similar vulnerabilities exist at other major U.S. ports: hurricanes in the U.S. Gulf Coast region, for example. Increased concern about threats of terrorists using containers could also seriously impede container flows through heavily used ports (Martonosi, Ortiz, and Willis, 2005).

The future direction and growth of the U.S. economy are undercut by major uncertainties that will affect the demand for freight movement. These uncertainties include the future level of international freight movement, fuel prices, how the country will accommodate and adapt to environmental issues, the form of future supply chains, locations and form of future manufacturing, and degree of offshoring and near-shoring. The ability of U.S. freight transportation to adapt to changes and unknown future directions of the economy will be important to permit flexibility for new growth.

The freight flow and design of the current system have developed largely through the independent actions of many stakeholders,

with very little overall coordination or planning. This means that the systemwide implications of local constraints, disruptions, fees and incentives, new infrastructure development, increased fuel prices, and traffic-mitigation measures are rarely understood from a freight-transportation point of view. Negative feedback loops abound. For example, logistics services develop in areas of major freight activity, reinforcing the movement of even more freight through those areas. Infrastructure that might attract freight, say, to an alternative port, is not developed because the current demand does not indicate an excess of benefits over costs. Central logistics-system planning has been key to the development of some competing economies, such as that of China (CSCMP, 2006). While such central planning may be anathema in the United States, a better systemwide understanding of the implications of regional and local changes could provide more transparency and motivate more-effective solutions and developments.

Another indication of the lack of flexibility of the current freight system is the continuing conflict between freight and passenger traffic. Freight trucks and trains use the same highway and rail systems as passengers in many urban areas, leading to additional congestion delays and constraints on the movements of freight during peak passenger periods. These conflicts can seriously curtail efficient freight movement, with a consequent economic drag.

Elements of a robust solution to improving the freight system's adaptability, survivability, and resilience include the following:

- Increase system-level modeling of the U.S. freight system that includes interactions between modes, regions, and components of the freight infrastructure. Such a model should be capable of simulating the reactions of independent users of the freight system to congestion, prices, constraints, new infrastructure, and disruptions at nodes and links of the infrastructure. Congruent with the development of such a model would be the development of freight-system data to support the modeling. Although some data are collected by local and federal transportation agencies now, much data are held privately for competitive reasons. For example, much of the data about rail-system performance and costs are

not available because they report on privately owned and maintained infrastructure. Because such data are necessary to understand the true system implications of public investments in infrastructure, agreements for sharing such data confidentially should be arranged. Part of the data collection should provide a better understanding of the distribution of sizes and types of businesses utilizing the freight infrastructure within certain regions.

- Identify key freight-system vulnerabilities—natural disasters, including earthquakes, hurricanes, and flooding; and vulnerabilities to terrorist disruption (including vulnerabilities to actions taken under heightened threats of terrorist disruption)—to disruption within the transportation system and possible responses to those disruptions. The aforementioned freight-system modeling would be used to understand the implications of the disruptions and the adequacy of the responses. It might also identify key pieces of infrastructure that would increase the robustness of the freight system and its response to the possible disruptions. Finally, systematic exercises should test the possible freight-system responses to disruptions. They could be tabletop or model-based exercises that simulate the emergency and response but that also help planners think through how the freight system will respond and function, in anticipation of the real thing.
- Offer incentives to encourage a more robust system of seaport use for international freight. These incentives could be in the form of differential container fees that encourage some users to use alternatives to the most heavily used ports. Leachman (Leachman, 2008; Leachman et al., 2005) describes a model and analysis that examines this alternative for West Coast ports. It may also be possible to construct selected infrastructure that improves the connectivity and robustness of the system. The Port of Prince Rupert in British Columbia has attracted major importers by offering direct rail links to the Midwest through Canadian railways.
- Provide infrastructure that separates freight and passenger traffic on rail and highways, particularly in urban areas. It may include grade separations; rail flyovers to separate passenger and freight rail; short-sea transloading to move freight to less congested ports;

and, as mentioned earlier, short-haul rail to move freight to less congested staging locations.

Issue 3: Addressing the Energy and Environmental Issues Associated with Freight Transportation

Rationale. Reducing energy use, thereby reducing dependence on foreign oil, has become an important priority for the United States, because of the influence of the cost of fuel on goods and services and because of increasing concerns about global warming. Transportation in the United States is responsible for about 25 percent of the country's hydrocarbon-fuel use, and freight transportation uses about 25 percent of that. The energy use for long-haul trucking, rail, and barge is 800, 300, and 500 BTUs per ton-mile, respectively (Federal Highway Administration, Office of Freight Management and Operations, 2008). Fuel costs have become a more significant factor in logistics costs. Consequently, reducing the energy use in freight transport can provide both significant cost savings and important environmental benefits.

The environmental impacts of local and international freight movement are large. Freight movement accounts for half the NO_x emissions from transportation and more than one-third of PM-10 emissions. As pointed out earlier, trucks emit about two-thirds of the freight NO_x emissions and about half the freight-related PM-10.

Environmental constraints can become major impediments to freight movement. For example, California's Assembly Bill 32 attempts to reduce greenhouse-gas emissions to 1990 levels by 2020. Applied narrowly at a port by limiting rail, trucks, ships, and other diesel-powered activity would imply limiting freight movement to the 1990 level. Even with a slower growth rate for freight than the experienced 4.7 percent, this would be a severe restriction. Mitigation measures, including developing more fuel-efficient trucks, providing electric power to ships at dock to avoid running the ship's engine for internal power while at the dock, limiting ship speeds near ports, and using electric locomotives, can reduce some of the greenhouse-gas emissions at the source, but, most likely, the port would need to purchase greenhouse-gas credits in a national or international cap-and-trade system. The costs of these measures would probably be passed on to users in the

form of increased container fees. Of course, the reaction of shippers (in terms of port selection for goods movement) to such fees is unknown, but the result is likely to be an increase in logistics costs.

One attempt to reduce emissions has been the Clean Truck program. This program provides loans to truckers for new, cleaner dray trucks. The cost of this program and the program's effect on independent trucks have become issues in its implementation.⁸

We note that passenger vehicles and not freight transportation are the primary energy users and emitters of pollution, and they need to be the primary focus of emission-reduction efforts.

Elements of a robust solution to reducing the environmental impact of freight transportation include the following:

- There are three basic approaches as outlined in the discussion below about the Dutch research (see Box 5.1): direct mitigation, efficiency improvements, and mode shift. *Direct mitigation* includes reductions in truck, ship, and rail emissions and fuel use through cleaner fuels, improved engines, and better aerodynamics. Driver education, training, and monitoring for efficient driving fall in this category, as does limiting of speed through engine modifications. At ports, providing electric shore power for docked ships and replacing diesel vehicles with those using battery power may be used to reduce local sources of pollution and energy use.
- Most efficiency improvements were discussed earlier in this chapter and in Chapter Four under the issue of managing and improving freight-transportation capacity. Most improvements attempt to remove unnecessary trips and miles (institute better routing, for example), reduce empty trips (develop IT-based Virtual Container Yards, for example), provide real-time information to avoid congestion, and reduce or shift demands. We discussed earlier that demands might be reduced by eliminating some packaging and shipping more-concentrated fluid products. Increasing truck-

⁸ See Port of Los Angeles Web site, "Port of Los Angeles Clean Truck Program" Web page, various dates.

load factors through IT-based load management, scheduling, and routing could reduce local truck trips.

- We showed earlier in this monograph the relative efficiency of trucks, trains, and barges. To the extent that goods can be economically shipped by rail and barge rather than by truck, the energy and environmental impacts can be reduced. Because of the limited routes available for these other modes and the generally slower and less-certain service, this alternative is difficult for local deliveries. Such deliveries are made largely by truck and are difficult for most regional deliveries involving distances less than 500–1,000 miles. However, for those goods traveling longer distances, the avoidance of truck transfers in some parts of a trip (avoiding drayage trucking at ports, for example) can be beneficial. Direct rail transfer from docks to distribution centers is an example of improved infrastructure to facilitate more-efficient mode use.

Issue 4: Making the Case for Public *and* Private Investment in Freight-Transportation Infrastructure and for Establishing Sustainable Priorities for Funding

Rationale. Generally, the funding for freight-infrastructure projects is problematic. The projects take many years or even decades to plan, gain public approval, and construct. Political support can be difficult to generate, because there is frequently no apparent benefit to a supporting politician's constituency during his or her entire term of office. Funding for freight-transportation projects comes from a multitude of sources—federal, state, local, and private—also making the coordination of support and priority-setting difficult. Often, the projects have perceived and real detrimental effects (increasing congestion, noise, pollution) for one or more local constituencies during construction or after completion.

Overall funding earmarked for highway and bridge transportation projects falls short, by 12.2 percent, or \$8.5 billion per year, of the estimated need for just maintaining the system at its current performance, and it is well short of that needed to improve performance, which would require an increase of 87.4 percent over the current

funding of \$70.3 billion per year (DOT, FHWA and FTA, 2006).⁹ Transportation-infrastructure projects that primarily benefit freight movement can be even more difficult to allocate and sustain because justifying the indirect benefit to the economy is a difficult argument for the public to appreciate. On the other hand, projects that directly benefit both freight transportation and passenger movement can generate the support to be successful. Some of the effects that reinforce local support include reduction in traffic jams at grade crossings; reduction of truck-related fatalities, emissions, and congestion; job creation; and near-term successes that could be credited to elected officials.

Another issue is that freight infrastructure and its needed improvements are not spread uniformly about the country or within urban regions. Generally, a limited number of corridors connect the major freight gateways with the rest of the country. Obtaining local funding for corridor or gateway enhancement that serves other parts of the country may be difficult, given that the benefits may not accrue to the local region (and, indeed, many of the negative impacts do accrue locally). Some areas far from the actual infrastructure may obtain significant benefits but are sufficiently removed that they may not perceive the need to contribute. For example, a considerable amount of the traffic through the POLA/LB serves much of the rest of the country, despite the fact that most of the negative impacts occur locally. This lack of transparency about cost and benefit (and about types of benefits—noise reduction, emission reduction, reduced energy use, congestion, jobs) due to the extent and complexity of the U.S. freight system is an issue to be resolved.

Developing equitable and sustainable financial strategies for freight-infrastructure development is a key aspect of the problem. Currently, at the national level, the motor-fuel tax, which is based on a cents-per-gallon rate, is the primary source of financing for U.S. highways and related infrastructure. This source of financing has eroded over the years because of improvements in vehicle fuel efficiency and

⁹ *Improved performance* of the highway system, in this case, means “positive net benefit to the American public in terms of travel time, vehicle operating costs, crashes, emissions and highway agency costs” (DOT, 2007).

the fact that the taxes have not been raised to match inflation and costs of infrastructure renewal. Other forms of financing public infrastructure are possible, particularly with today's technology for vehicle tracking and automated billing, including fees tied to VMT, type of vehicle, type of roadway, and time of use. Other possible revenue sources include special taxes or assessments, customs duties, and container fees. In addition to financing infrastructure, various fees can be used to promote different behavior among users—travel at noncongested times, reduce fuel use and emissions, and utilize alternative modes and routes in the system. Most proposals raise objections from various and differing groups of stakeholders: about fairness, whether the money raised will really be used for infrastructure development, and how progressive or regressive the taxes are.

Some of the infrastructure required will be privately funded, such as improved rail connections to ports and rail-capacity increases.¹⁰ How to motivate and sustain the PPPs necessary to expand and improve the private infrastructure is an important aspect of the problem.

Elements of a robust solution to funding freight transportation include the following:

- Establish a framework for priorities in freight-infrastructure development and link the priority developments to public benefits. An illustration of such a freight-improvement framework is provided by a freight-transportation study performed for the Dutch that dealt with many of the infrastructure, energy, emissions, social effects, and economic impacts examined in this document (see Box 5.1). The framework for that study included multiple growth scenarios; a large number of options for improvement; a complete set of freight “impact” measures, including various economic measures (jobs, added value, costs), emissions, energy use, congestion, survivability, resilience (to built and natural disasters), noise, and safety; a model to relate the scenarios, tactics, costs, and impact measures; and a scorecard that permitted decisionmakers

¹⁰ Also, private funding and building of highway infrastructure, reimbursed through user fees, is being practiced increasingly to build critical links in the highway system.

to examine the implications of relative emphasis on the measures on the ranking and cost-effectiveness of the options. Figure 5.2 illustrates the structure of the model used in the Dutch study.

Box 5.1 (Hillestad et al., 1996a).

In 1996, RAND researchers performed a comprehensive study of freight-transportation policy in the Netherlands (Hillestad et al., 1996a). Similar to the current situation in the United States, European freight-transport demand had experienced strong growth for many years, and road transport had increased more than 30 percent in the prior decade. Moreover, the freight road traffic was expected to double in the next 25 years. Along with the concomitant prosperity of this increase was a predicted increase in emissions, accidents, noise, and congested roadways. Continuing policy debate on the best way to handle the freight-transport problem led the Dutch to commission the RAND study. The study analyzed the benefits and costs of more than 100 policy options or “tactics” for mitigating the negative effects of the expected growth in road transport while retaining the economic benefits. The effects of the tactics included economic benefits, costs to implement, emissions, energy use, accessibility, congestion, and noise. The options fell broadly into three categories: direct mitigation, transport efficiency, and mode shift.

Direct mitigation focused on reducing one or more of the negative effects at their source—for example, building cleaner diesels to reduce emissions or using speed limiters on trucks to reduce emissions and accidents. Transport-efficiency policies or tactics focused on using the truck fleet and transport infrastructure more efficiently—for example, rewarding truck drivers for more-efficient driving or for using larger trucks. Mode-shift tactics were designed to stimulate the shift of freight off the roads and onto other

Box 5.1—Continued

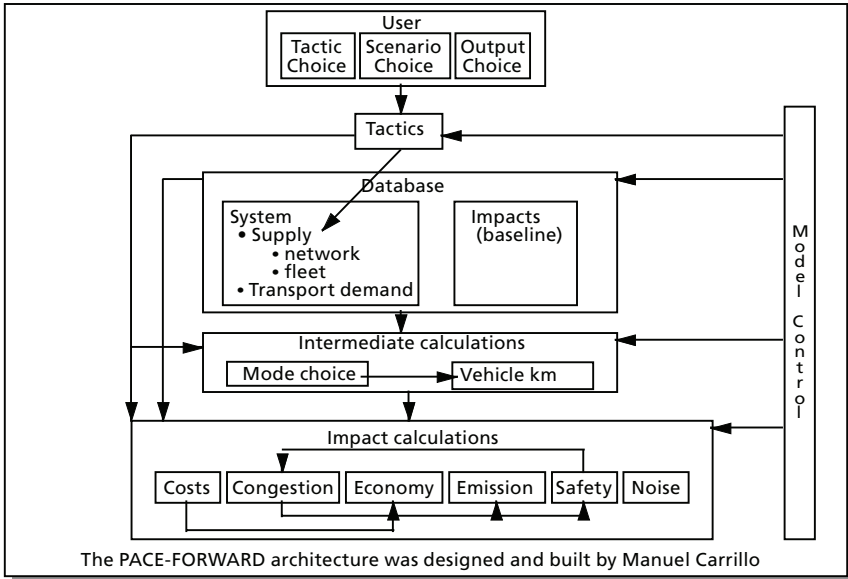
modes of transport—primarily, onto trains and barges. These tactics included better interfaces between the other modes and trucks, and pricing incentives to shift modes. The various tactics were modeled and measured the effect on various measures, including congestion, safety, emissions, and economic effects.

In the end, the study found that the most important policies were those that improved transportation efficiency. They not only reduced many of the negative effects of freight transport, they also reduced costs and made the Dutch system more competitive. For example, reducing the number of truck-kilometers traveled, through telecommunications and IT to improve routing and matchup of demand with capacity, improved all measures and saved money on transportation. Allowing larger trucks consistently across the European Union had a similar effect. Rewarding truck drivers for efficient driving not only reduced fuel costs but also reduced truck emissions. These policies or tactics did not need to wait for large infrastructure changes and had the added advantage that the burden of implementation did not fall on a single stakeholder group. Some of the direct-mitigation tactics, such as developing cleaner diesel engines, were found to be cost-effective, but they generally targeted particular impact measures. Tactics encouraging mode shift from truck to rail or barge generally had limited beneficial effects because of the short distances for European freight and the problematic service characteristics of the European barge and rail modes. Finally, infrastructure developments (such as truck lanes) were found to be most beneficial when they fostered additional efficiency or productivity of the goods-movement system.

Most of the Dutch lessons are applicable to the U.S. system, and we have reached similar conclusions in our survey and analysis of U.S. freight transportation:

- Future scenarios for economic development and transportation demand need to be considered. The validity and uncertainty associated with projections of freight movement are important. Projections may be wrong because of future economic growth or lack

Figure 5.2
Model Structure for Evaluating Freight-Transportation Improvement Options



SOURCE: Carrillo et al. (1996).

RAND MG883-5.2

of growth, new business models, or changes in population and consumer demands, for example. Robust priority-setting would consider these alternative futures.

- Establish local and regional priorities in the context of the broader system model of freight transport in the United States, which considers how regional changes in infrastructure, costs, or constraints affect the broader freight system.
- Bring the private sector into the planning and decision process at an early stage. Public-private partnerships are likely to be an important element of the funding solution, and the private sector is a source of ideas that improve productivity.
- Develop equitable and sustained funding approaches that utilize the best information from transportation economic theory and actual experience with the approaches (in the United States and

elsewhere) and that may use advanced technology, such as Global Positioning System (GPS) tracking where appropriate. Develop PPPs where possible and appropriate.

Final Comment

We note that this monograph suggests a fairly large menu of actions and that these actions involve all stakeholders to some extent. We do not go so far as to suggest who should be in charge or provide funding, but a key next step is to further refine responsibilities, achieve consensus among stakeholders on priorities, and define sustainable funding streams.

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