

# Freight Systems

## From System Construction to System Optimization<sup>1</sup>

### ■ Executive Summary

In recent decades, the freight transportation system has been in transition from an era focused primarily on system construction toward an era that will focus increasingly on system optimization. Past efforts at developing the transportation infrastructure were oriented around system construction. The railroads in the 19<sup>th</sup> century and the highway system in the 20<sup>th</sup> century connected all parts of the nation, and opened up markets for moving freight and passengers. Today, these systems are extensive and mature. Ports, airports, and other freight systems have been developed, and technological and management change has increasingly focused on optimizing the use of available physical assets. Those mature assets require large expenditures of resources to maintain and preserve asset conditions, meaning that fewer resources are available to build new capacity.

Optimizing freight operations and productivity has occurred within the context of deregulation, economic globalization, and increasing congestion on the nation's transportation system. Deregulation has resulted in excess capacity being eliminated from highway and rail freight services and facilities. Intermodal services and facilities have revolutionized international trade, and made all modes more productive. Ports and airports have seen services and demand grow rapidly. Freight services are now more efficient and in many cases lower in cost (in constant dollars) than in previous decades. But the elimination of excess capacity has resulted in systems with less redundancy and less ability to withstand shocks or disruptions. Congestion is growing on many key freight segments of the transportation system, and congestion can drastically reduce the productivity of the overall freight network. This congestion and incident-related delay could vastly increase the costs of those freight movements that are today managed to exacting schedules.

By definition, optimization of a system means that the highest productivity is being squeezed out of that system as it currently exists. If new demands are placed on the

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optimized systems, then those demands must be met through a coordinated set of capacity and system optimization enhancements. Further, a less redundant system also means that the impacts of work zones must be more carefully managed. Finally, major surges in movements, such as defense or emergency deployments, also require more attention in a system already operating at peak capacity.

The public and private sectors are faced with two questions: What is the best response to growth in demand for freight services? How can a coordinated program of actions that takes full advantage of new technologies as well as of the traditional attributes of the nation's successful freight systems be developed? Freight decisions must be made across jurisdictional boundaries and across boundaries that currently exist between public agencies, private carriers, shippers, and the affected communities and interests from the local to the global level.

## ■ Introduction

Transportation systems, like other infrastructure systems, experience a logical life cycle. When first developed, a transportation network provides new linkages and capacity, opens up new markets, and introduces superior service capabilities. The railways in the 19<sup>th</sup> century and the highways in the 20<sup>th</sup> century united the continent with transportation services that proved a boon to economic development. In recent decades, airfreight, huge bulk vessels, and ever-larger container ships have created tremendous productivity improvements in international shipping and made possible the global economy. Over time, however, demand catches up with capacity, maintenance and rehabilitation requirements rise, populations and economic activity shift, and bottlenecks and inefficiencies emerge in the transportation system. More resources must be devoted to maintenance and preservation of facilities and services, and fewer resources are available for expanding capacity or adding new or improved services. Increasing attention is devoted to doing the best with what is available by emphasizing operations. This can be characterized as a shift from system construction to system optimization.

This transition has been underway in the rail industry for decades and is increasingly a focus for highways. System optimization is a driving force for the rapidly growing intermodal system. Intermodal services and facilities have grown around opportunities for system optimization, utilizing available capacity by making selected operations and capital investments that provide cost savings and improvements to services.

System optimization is a broad concept that includes incremental adjustments, modifications, enhancements, and upgrades to infrastructure, vehicles, information technology, management practices, and improved operations. Specific examples of system optimization, which may involve investment in new capacity, include the following:

- Selected improvements to capacity or selected service changes to eliminate or avoid bottlenecks and to exploit underutilized facilities;
- Improved components for vehicles and facilities to reduce life-cycle costs;

- Vehicle technology to allow improved utilization;
- Introduction of improved information technologies to allow better utilization of the infrastructure; and
- Improved operations and service planning by carriers and third-party logistics suppliers to provide marketable services.

System optimization incorporates the responses of customers, the public, and the economy to the transportation system – specifically, the adjustments that they make in terms of their own travel and locational choices. New facilities and new services that are introduced to optimize the system affect how logistics systems are structured and how much freight flows over each part of the network. Government agencies respond to transportation capabilities through regulatory and policy actions. In turn, responsive policy-making requires ongoing adaptation to changes in technology, infrastructure, and economic behavior.

Both system construction and system optimization have led to tremendous improvements in productivity in the freight industry. It is natural, then, for much of the discussion in this theme to revolve around where future productivity gains might emerge or be encouraged to emerge.

While system optimization has many positive impacts, it may also have a few unintended impacts. For example, the focus on system optimization has resulted in much less redundancy in systems, but redundancy means fewer response options to incidents or special circumstances, or to rapid growth. Work zone management becomes more important and more challenging. As national defense becomes more dependent upon excellent strategic mobility, the systems may be less able to cope with surges in defense flows. Intermodal connectors, ports, and airports are of concern both as bottlenecks impacting normal freight flows and as potential constraints on defense capabilities.

This paper explores the trends, implications, and issues involved in the shift from system construction to system optimization.<sup>2</sup>

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<sup>2</sup>The information and analysis in this paper are based on a literature scan that was conducted in the spring of 2000 and a series of informal interviews that were conducted in the summer and fall of 2000 with federal, state, and freight industry officials. The interviews were not for attribution in order to encourage candor. The objective of the paper is to explore and organize initial ideas on freight trends, implications, and issues. The paper is not intended to be a definitive treatment of the topic.

## ■ Trends

### Freight System Productivity

For a variety of reasons, the freight industry has achieved remarkable productivity improvements in recent decades. Substantial benefits have come from general economic growth and declining real dollar labor and fuel costs. Economic growth almost automatically generates more capital for investment by industry, although the public sector resources generated through fixed per gallon fuel taxes do not respond automatically to economic growth. Technology has also played a major part, not just in the rapid advances in computers and telecommunications, but in the development of larger, heavier, and more fuel-efficient trucks. Deregulation and other policies aimed directly at freight productivity were successful in fostering network restructuring, fostering efficiencies in the use of labor and equipment, and reducing prices paid by freight customers.

New transport services have been introduced and existing transport networks have been expanded. Reductions in airfreight costs and innovations in operations have led to the development of overnight express networks, sparking a revolution in specialized land and intermodal services to serve what was once the much maligned small package segment of the freight market. The Interstate Highway System has provided capacity for much faster and more reliable movements in larger, heavier trucks.

The capacity of the mainline rail system has been dramatically increased, in large part through its conversion to a heavy haul network capable of more throughput in longer and heavier trains. With help from government agencies in increasing clearances, railroads have introduced a national network for operating double-stack container trains. Despite the conversion of many multi-track lines to single track, the capacity of the mainline system has increased. Excess potential capacity is gone, however, and today many parts of the rail network are operating at their maximum capacities. The productivity of double-stack trains has transformed the relationships among railroads, motor carriers, ocean carriers, and third-party logistics providers. These changes have led to containerized shipments, increasing dramatically the demand for domestic as well as international shipping. Very significant investments have been made in ports and other intermodal terminals in order to increase the capacity of the system for handling the rapidly growing volume of container shipments.

Today, a much greater variety of freight transportation services is provided over improved networks than just 30 years ago. The proliferation of services and improvements to the networks proved a boon to shippers and a major source of productivity improvements to the carriers. In short, the U.S. economy now benefits from an ubiquitous truckload (TL) and less than truckload (LTL) system, as well as extensive intermodal, rail, air, and express freight systems. Along major waterways and along the coasts, there are extensive low-cost barge and ocean shipping operations. All of the enhancements to these systems and services have provided customers with new location options and new logistics choices that can be exploited to competitive advantage. The result has been that freight transportation costs and prices – in real terms – declined over the latter quarter of the 20<sup>th</sup> century.

However, over the next 20 to 30 years, there will be a far greater need to maintain, rehabilitate, and optimize the existing networks and less opportunity (domestically) to expand the networks and services provided. The resources required for system maintenance and preservation limit the availability of funds for capacity expansions. Increased scrutiny of projects and increased concern about environmental and community impacts also narrow the choices. For highways, it appears unlikely that truck size and weight limits will change in any manner that would lead to substantial new productivity gains. A “bridge formula” limits allowable axle weights and configurations in order to protect the nation’s bridges. Legislatures have shown sensitivity to concerns about the overall size and weight of trucks. For railroads, any increases in weights for rail cars would have less of a percentage impact on productivity than historical changes in rail car weights.

The potential inability of infrastructure capacity to keep up with steadily increasing demands is a theme that has echoed throughout investigations into the future of freight transportation in America. Carriers, customers, and government agencies are all concerned about the difficulty of adding capacity and of overcoming congestion. Congressional hearings in 2001 have focused on congestion and the viability of solutions. Issues of capacity and congestion, to a greater or lesser extent, are of major concern for all of the freight modes. Emerging problems include the following:

- Portions of the freight system require substantial rehabilitation (e.g., inland waterway system; highway and railway bridges);
- The costs of congestion and of delays associated with key bottlenecks are significant and increasing;
- The rising costs for land, fuel, and labor threaten to offset recent gains in productivity; and
- Increasing difficulties in obtaining land and financial resources for expanding facilities limit the additions that can be made to capacity.

There are no current proposals for massive new programs to add capacity. The nation’s most significant highway capacity initiative, the Interstate Highway System, is nearly completed. Building more capacity will become more and more difficult, not only because of the lack of funds, but also because of the increasing social and economic cost of neighborhood and environmental impacts.<sup>3</sup> As the system ages, maintenance and rehabilitation have become the new focus.

Although some new highway lane-miles continue to be added, they are not being added quickly enough to stave off more and more traffic-related delays. The capacity issue for highways is an issue of location and time of day. Based on the total number of national lane-miles of highways and roads, and total vehicle miles of travel, the average density of travel across the system is calculated at some 40 vehicles per hour per lane-mile, which

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<sup>3</sup>See related theme paper in this series, “Environment: From Low Visibility to Environmental Accountability,” available at <http://www.ops.fhwa.dot.gov/freight/adfrmwrk/index.htm>.

would not be defined as congested. However, the most important facilities are highly congested at particular times of the day, and on those facilities, congestion is spreading over more hours. Selected spot or bottleneck improvements, new lanes or new facilities, or new modal options can help to relieve congestion. Still, resources are so limited that many agencies can now address only a few capacity issues every year, and are unable to keep pace with travel growth.

Congestion in the vicinity of cargo hubs (e.g., ports, intermodal terminals, rail yards, and warehouse districts) has become a particular problem because many of these facilities are located in the older, more densely developed industrial areas of metropolitan areas. State and local governments can and are investing to improve freight access in congested metropolitan areas, but building public support for these investments is often difficult. The costs are borne locally, but the benefits often accrue over many states. The political struggle over who pays and who benefits hamstring many freight projects.

Foreign trade is an increasingly important part of the U.S. economy. However, many ports are running out of room for terminal expansion, and highway congestion threatens to impede access to ports. The U.S. Department of Transportation's recently completed report on the condition of the National Highway System (NHS) intermodal freight connectors underscored the problem, with data showing that the condition of intermodal roadway pavements and the level of investment in their repair lagged significantly behind the average for other NHS roadways.<sup>4</sup> The move toward ever-larger vessels and load-center ports could exacerbate this problem by creating demand for even greater throughput at facilities that are already perceived as bottlenecks.

Barges are major movers of grain and bulk products. However, many locks and dams are aging and in need of improvement. Moreover, portions of the system have low utilization, and there have been suggestions that some of the inland waterways system should be returned its natural state.

Air cargo also is becoming increasingly important in this age of high-value commodities and direct-to-home shipping of consumer goods. However, air cargo competes for landing slots and for airport space with passenger needs, and it is very difficult to increase airport capacity. The new Denver airport is the only entirely new, major facility that has been completed in the last two decades. Most existing airports have found it difficult politically, if not physically impossible, to add new runways in order to increase capacity.

Since freight traffic is expected to continue to increase, the problem of ensuring sufficient capacity will become more prominent. Indeed, in order to continue to provide efficient and effective freight transportation services, it will be essential to pursue creative approaches to increasing productivity and expanding system capacity, while reducing negative impacts on neighbors and the environment.

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<sup>4</sup>See *NHS Intermodal Freight Connectors, Report to Congress*, U.S. Department of Transportation, July 2000, available at <http://www.ops.fhwa.dot.gov/freight/adfrmwrk/index.htm>.

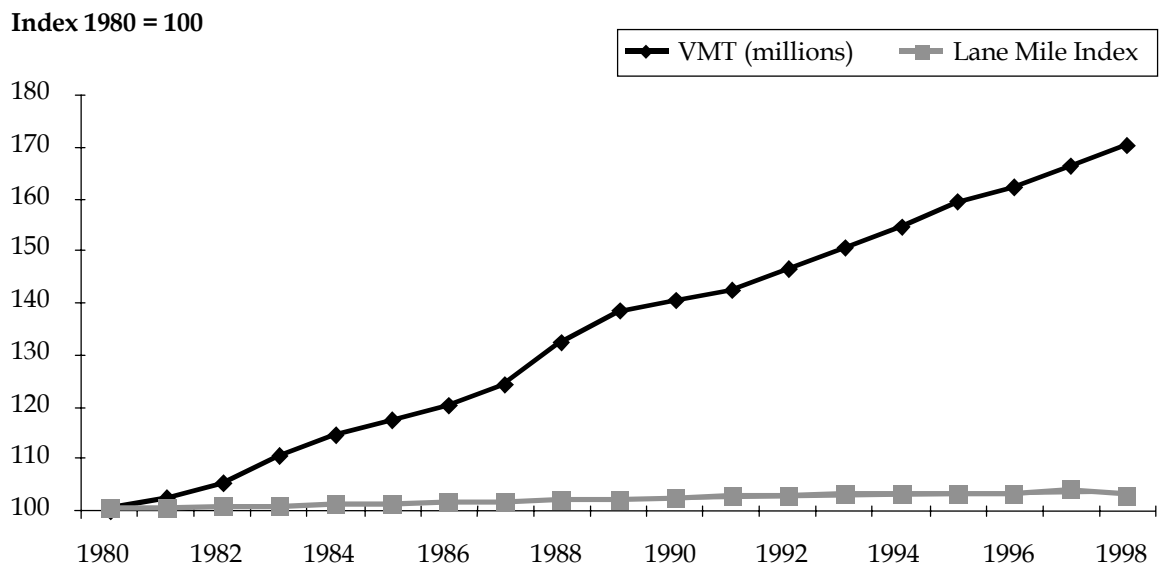
## Capacity Investment Trends and Implications

### Highway

Emerging environmental concerns, the increasing cost of facilities, and increasing congestion have limited the ability to create major new highway capacity in most parts of the country. Highway system expansion has not kept pace with the growth in vehicle miles of travel (VMT). As shown in Figure 1, VMT rose 72 percent between 1980 and 1998, while over the same period the number of roadway miles increased one percent. While capacity in terms of roadway miles does not have to directly track VMT in order to maintain service levels, the lack of new capacity almost assures that service levels will deteriorate unless massive shifts in travel patterns occur. However, traffic grew on most facilities, and those close to or at capacity experienced significant problems due to additional delays and spreading of the peak periods.

**Figure 1. Growth in Vehicle Miles of Travel and Road Miles**

*Vehicle travel grew by 72 percent, road miles by 1 percent between 1980 and 1998*



Source: Federal Highway Administration, Highway Statistics.

With maturation of the Interstate Highway System, the development focus for highways has been on linkages, through designation of the NHS, the national defense Strategic Highway Network (STRAHNET), and intermodal connectors.

### Rail

Capacity for other modes has also failed to keep pace with the growth of traffic. In the case of rail, the length of the mainline track network has actually declined, along with the number of locomotives and rail cars. Despite this reduction, rail ton-miles have increased, due to heavier cars, longer trains, and faster throughput. Today, the nation relies on fewer rail cars and locomotives to haul more freight than ever before. Excess capacity and redundancy – in effect, the “slack” in the system – are gone from the network. As an

unintended consequence of tightening the slack, operations have become much more susceptible to breakdowns from the loss of a specific link due to incidents or other causes. The lack of redundancy also decreases the options available to shippers and customers. Options have value to shippers in terms of increasing competition and holding down rates.

The overall route structure of the nation's mainline rail system has been changed only modestly since 1975. The most notable expansions have been in the creation of mechanized intermodal terminals, often by converting former marshaling yards. Despite the creation of many new short-line and regional railroads, the network of light density rail lines has also continued to shrink, continuing a process that began early in the 20<sup>th</sup> century.

In recent years, the rail industry has begun to focus on rationalizing its network. A succession of mergers and acquisitions has left the nation with a handful of very large (Class I) railroads operating on a significantly consolidated mainline network with connections to many light density lines served by a large number of short-line and regional carriers.

### ***Ports***

In the last 25 years, U.S. coastal ports and coastal and inland waterways have undergone major improvements. These improvements have come primarily in response to the container revolution and growth in bulk trades, as well as to competition among ports seeking the economic benefits associated with trade. Containerization has driven much of the growth in port tonnages. More containerization and larger vessels have resulted in faster offloading and quicker turnaround. While almost all coastal ports experienced growth over the last 25 years, ports on the west and southeast coasts experienced the greatest growth, reflecting changes in U.S. trade relationships. However, obtaining additional landside access, constructing major landfills for port expansion, and implementing major channel deepening projects all involve long and difficult processes.

In interviews with carriers, concerns have been raised that the land “crunch” for freight-related facilities is becoming a major problem. Port and intermodal facilities and related terminal and service facilities will need to be expanded, but these facilities are concentrated in older centers where land available for expansion is severely limited. One metropolitan planning organization, the North Jersey Transportation Planning Authority, has compiled a list of “brownfields” – abandoned industrial sites in urban areas – that may be appropriate for port-related uses. “Freight-oriented development,” like “transit-oriented development,” could play an important role in the economic revitalization of downtown areas, while reducing pressure to develop unspoiled land outside the city limits.

### ***Economic Geography and Location Trends***

When considering trends in freight flows and productivity over the course of several decades, it is necessary to recognize the importance of fundamental trends in economic geography, i.e., in the distribution of economic activity around the globe. A major factor driving the growth in intermodalism and developments in intermodal technology, for example, was the increase in imports from the Pacific Rim and the need for low-cost

transport from the west coast ports to the major markets in the central and eastern parts of the U.S.

For the railroads, shifts in the market for coal have had major consequences; coal accounts for roughly 40 percent of the industry's tonnage. Environmental considerations have led to greater use of low-sulfur coal, which has affected coal freight flows dramatically. The production of coal from Wyoming's Powder River Basin has increased rapidly over the past 20 years, leading to increased coal movement on the western railroads. In the east, coal production and coal transportation have declined because of lower foreign demand and because of a shift toward low-sulfur western coal. The use of alternative energy sources and the possibility of mine-mouth generation are two other factors that may affect the long-term demand for coal transportation.

Agriculture is highly sensitive to changes in transportation services and costs. Today, American farmers successfully compete in world markets thanks to competitive rail service and low-cost barge and ocean shipping, but major shifts in agricultural production and distribution could occur within 20 to 30 years. For example, soybean production is growing rapidly in Brazil and Bolivia, where agricultural production costs are well below what they are in Iowa, the most important soybean producing state in the U.S. As the transport systems improve for South American agricultural products, soybeans and other agricultural products will become more competitive worldwide, with important implications for U.S. agricultural production and transportation systems.

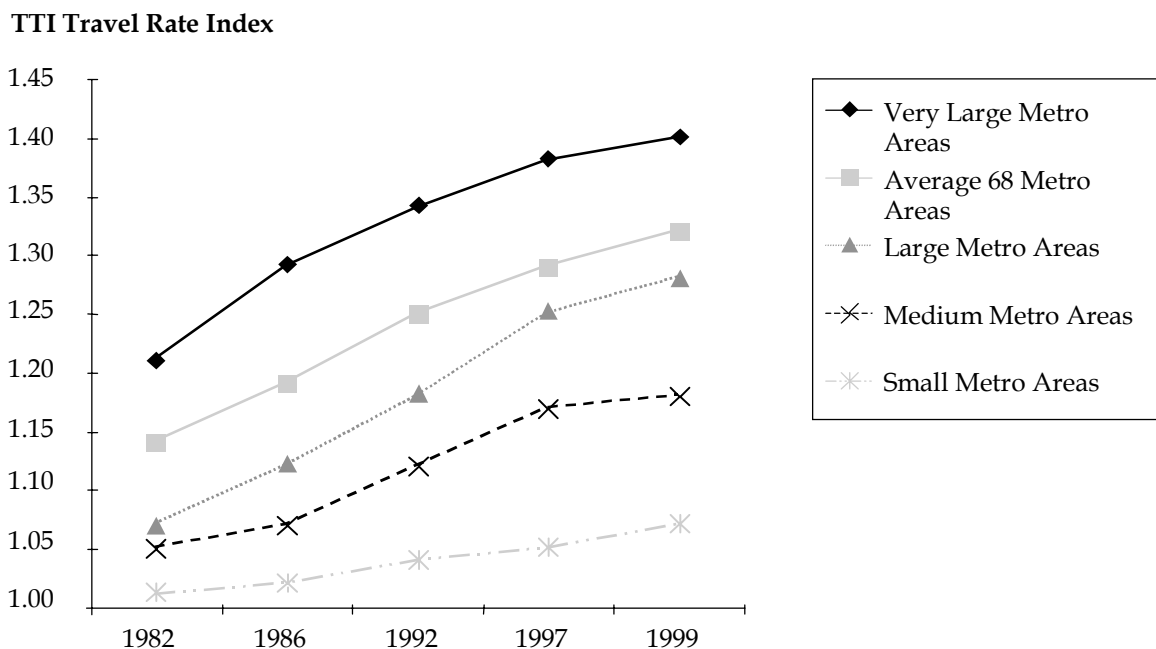
The changes in markets and economic geography also open up opportunities for new linkages, including new terminals and services. Every change in market forces creates opportunities for investments that take advantage of the enhanced productivity or lower cost of moving freight from a place of production to an ultimate market.

## **Congestion**

The Texas Transportation Institute (TTI) monitors highway congestion in metropolitan areas across the nation with a measure called the congestion index, which is the ratio of travel time in the peak period compared to off-peak periods (Figure 2). The congestion index in metropolitan areas of all sizes has increased dramatically since the early 1980s, and is expected to worsen in the future. Likewise, TTI also estimates the costs of congestion, which have been increasing significantly year by year.

Freight carriers and shippers experience congestion-related losses in several ways. First, trucks need access to ports and terminals that are often located in the most congested parts of the most congested urban areas. Second, trucks need to make deliveries to customers in these congested cities, at times of day where street space is at a premium. Third, trucks are often blamed for congestion problems, and their needs are seldom well understood by the public and by transportation decision-makers at the local and regional level. All losses due to congestion are passed on in terms of higher prices and lower economic productivity, impacting all consumers and all industries.

**Figure 2. Travel Rate Congestion Index**  
*Peak-Period Travel Times Have Increased Significantly Compared to Off-Peak Travel Times in 68 Large Metro Areas*



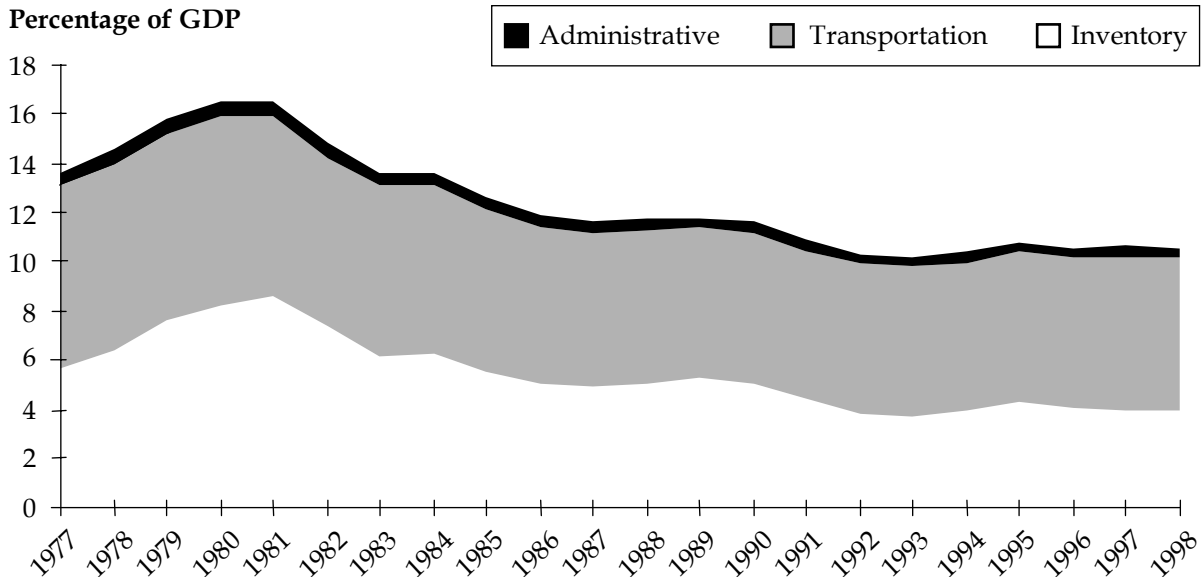
Source: Texas Transportation Institute

*Note: Congestion index is the ratio of travel time during peak periods to travel time during off-peak periods.*

## ■ Implications and Opportunities for Further Productivity Improvements

Many of the major factors driving productivity improvement in freight transportation over the past 20 years have largely been exhausted, making continued improvements more difficult to achieve in the future. Figure 3 shows the trend in total logistics costs. In recent years, these costs have stalled at about 10 percent of gross domestic product (GDP). The flattening of the curve suggests that shippers and carriers have wrung most of the cost savings out of deregulation. Shippers are spending proportionally less on transportation today compared to 20 years ago. Not only are they spending less, they are also getting much more transportation for their dollar. Deregulation has lowered transportation prices and improved quality, allowing shippers to substitute low-cost transportation (in the form of frequent, just-in-time deliveries) for high-cost inventory. The combination of lower transportation costs and reduced inventory carrying costs saved businesses and consumers billions of dollars.

**Figure 3. Logistics Expenditures and GDP**  
*After a Long Improvement, Total Logistics Expenditures  
 Have Stalled at About 10 Percent*



Source: Cass/ProLogis 10th Annual State of Logistics Report, 1998.

In the future, returns from deregulation could diminish, forcing the freight transportation industry to look beyond deregulation to maintain and improve its productivity. The next sections explore some of the opportunities for further improvements in productivity in each of the freight systems.

## Rail Industry Productivity

### *Hubs and Terminals*

The rail industry, after decades of plant reduction, now finds itself short of capacity in certain key lanes and terminal areas. The problem is particularly acute at hubs and terminals where carriers exchange traffic, where they share facilities, or where one carrier's operations interfere with another's.

The Chicago region represents the most critical example of this issue. Although industry consolidation over the past 20 years has resulted in six large North American systems, Chicago has not lost any of its significance as the primary rail gateway between east and west. Although alternative gateways are available for the four major U.S. systems, network configuration continues to favor routing through Chicago. This affects all types of traffic that must travel between east and west, including unit trains, carload shipments, and intermodal shipments. For most connections, trains must be routed through heavily congested connecting lines, yards, and terminals that were designed to meet 19<sup>th</sup> century requirements. Furthermore, in many cases, the traffic must be handed off to one or more

switching roads (primarily the Chicago Belt Railway and the Indiana Harbor Belt) for classification and delivery to the connecting road.

On a typical day, the Chicago region hosts 33,000 cars and 1,200 locomotives, along with 44,000 pieces of intermodal equipment. Twenty-five percent of the nation's rail freight originates or terminates in Chicago. A significant portion of this figure involves the drayage of intermodal trailers and containers from one rail intermodal facility to another, a direct result of the complexity and inefficiency in providing steel-wheel interchange between eastern and western carriers. In late 2000, the Association of American Railroads (AAR) reported that the connection time for rail-bound carload traffic through Chicago was approximately 40 hours. Other sources at recent meetings in Chicago have cited 72 hours. While a significant improvement over the 90 to 100 hours that were common during the depths of the various merger-related service crises in recent years, this performance is still costly and uncompetitive.

The severity of the merger-related service problems in Chicago prompted the creation of a special AAR committee with responsibility for improving day-to-day coordination and also for developing longer-term approaches to dealing with capacity and performance problems. Although the short-term operational actions have had positive results, achieving consensus among the carriers on more comprehensive solutions involving substantial operational changes and/or capital investment will be difficult, if not impossible. Even if agreement could be reached, the price will likely be too high for the railroads to tackle by themselves, no matter how great the expected savings and/or revenue gains from improved service. The magnitude of the problem is sobering. The annual cost of inefficient Chicago operations just for intermodal service is estimated to be at least \$500 million. Add the delays in moving general freight through the region, and the national significance of this terminal area becomes more evident.

Solutions to such complex problems as these will require new models for management and operations, such as the Alameda rail corridor that serves the ports of Los Angeles and Long Beach. A publicly owned rail authority conceivably could acquire the key rail lines within a metropolitan region, and the private railroads could become tenants. The public authority would then undertake capital improvements funded through the Transportation Infrastructure Finance and Innovation Act (TIFIA) credit program or other federal programs, and the railroads would pay the authority on a per-car basis for use of the facilities. Obviously, such a new approach would not be without risk. However, further progress on the hardest problems will likely require riskier and bolder initiatives than those taken in the past.

### *Rail Service*

Railroads have sought to retain some truck competitive traffic through deep discounts in pricing, but this has led to a vicious cycle of cutbacks in operations and further deterioration of service. The traditional carload business is particularly susceptible to further declines in service and volume. Unlike intermodal and unit train services, the carload product has not improved over the past 30 years and, in recent years, has suffered through prolonged periods of particularly poor service. Poor service has sometimes been related to mergers and consolidations, as evidenced by the aftermath of the Union Pacific-Southern Pacific combination. The railroads' service profiles are another cause. For example, through competitive pricing, the railroads have induced shippers to load

multiple carloads. As a result, many agricultural communities have been faced with the choice of either losing their access to competitive shipping rates and services or investing in infrastructure that supports unit-train loading. These issues have been discussed in many forums including the Western Governors' Association Freight Partnership meetings held in coordination with the Federal Highway Administration (FHWA) and the states, railroads, and shippers.

According to some officials, the industry could be headed for another phase of plant rationalization and downsizing, with substantial amounts of freight forced onto the highway system. Some industry officials have sought a fundamental change in the business model for dealing with the carload business. One option would entail establishment of a reservation system in order to reduce demand volatility, allow railroads and their customers to plan more effectively, and move freight more efficiently and reliably. By smoothing demand and matching service commitments to the available capacity, utilization can be increased while service reliability is improved. Another would be to encourage shippers to own their own rail cars. While this solves the problem of car availability, it does not solve the problem of car scheduling.

### *Technology*

Innovation in basic railroad technology will continue. More durable track materials are being developed and tested by the AAR as part of its continuing effort to reduce track and equipment costs. In particular, the rail industry has an extensive research program aimed at developing track technologies to allow increases in axle loads and higher density loading of vehicles. In the past 30 years, the industry has already increased the typical limit for gross vehicle weight by over 40 percent, from 200,000 pounds to 286,000 pounds. A further 10 percent increase to 315,000 pounds is now under consideration. Such an increase would have implications for short-line railroads, which would be forced to make investments to accommodate the heavier cars, and for rail transit providers, which share rail lines in some urban areas with freight trains.

Another set of initiatives is aimed at what might be called "precision railroading." Advanced train control systems are probably the most well known example, with their potential benefits in terms of safety and line capacity. On-board computers and wireless digital communications offer substantial operating advantages to railroads and provide a platform for innovative information technology (IT) applications. Electronically controlled pneumatic braking systems, which are in the initial stages of deployment, offer greater control over train braking, permit safer operations, and allow for shorter stopping distances. Remote-controlled locomotives, which are used throughout Canada for yard switching, could be widely used in the U.S. as well. Moreover, the concept of remote control might eventually be extended to some line operations, as has already been done in some transit systems. The Meteor line of the Paris metro, the first segment of which began operating in the late 1990s, is driverless.

### *Mergers*

There may be further efforts at restructuring the rail industry, including continuation of trends regarding mergers and short-lines. Some observers believe that the industry is headed to two major transcontinental systems covering the U.S. and Canada, which will help reduce the inefficiencies associated with complicated east-west interchanges at

Chicago, Memphis, St. Louis, and New Orleans. However, further consolidation will only reduce the level of competition within the rail industry itself. Captive shippers believe that they will suffer in terms of both services and rates as a result.

## **Motor Carrier Productivity**

### *Information Technology*

Motor carrier officials expect information technology to drive a great deal of productivity gains. One common objective is to use IT to coordinate more effectively with customers to reduce the general randomness of freight in the system and to provide a higher level of service to the customer at a lower cost. The average length of haul has declined for truckload carriers, obliging them to focus more on equipment utilization.

### *Intermodal*

Truckload and LTL carriers are using rail intermodal options, which frees up highway capacity in congested corridors and may provide productivity gains for the carriers. The substitution of a rail move for a highway move can in some circumstances improve the cost structure for over-the-road truckers. One official noted that the trucking industry and the rail industry will also seek to use intermodal options to address seasonal and regional flow imbalances, e.g., in moving empty containers back to west coast ports during peak shipping seasons.

According to customers, intermodal service has not only recovered, it reached an all-time high after the service disruptions associated with recent rail mergers. However, this is the perspective of a high-priority customer willing to pay for premium service. A larger question is how much motor freight could reasonably be converted to intermodal and handled efficiently within the capacity constraints of the rail system, while taking into account the generally thin profit margins achieved by this traffic. Even if the amount of intermodal traffic doubled, it might have only limited impact on highway truck traffic volumes because of the projected high overall freight growth as well as the longer-distances (500 miles plus) required for intermodal to be most effective. Intermodal operators feel that productivity gains must come from better planning, terminal rationalization, more effective use of information technologies, and asset management strategies, because the trains will not run any faster. Operators favor the development of major new or expanded hub terminals because these are more efficient in terms of workload and in terms of providing connections to the rest of the network.

### *Networks*

The national LTL carriers have achieved productivity improvements by restructuring their terminal networks and making greater use of rail intermodal options for line-hauls. One of the national carriers, for example, was able to cut a full day out of transit times by restructuring its terminal network to increase the number of direct shipments. Even though its trucks run no faster than they did 10 years ago, the company now provides better service. Carriers also have made effective use of warehouses located and designed to achieve productivity gains, for example in terms of physical location, proximity to other related land uses, and highway access. On-time service for the LTL carriers is believed to be in the low 90 percent range. This means that carriers can generally provide 95 percent

on-time deliveries to a large percentage of major customers, but on average have not achieved 95 percent on-time systemwide. Desired service levels, however, are a shifting target, and some customers want deliveries planned to the minute, which makes it more difficult for the carrier to develop efficient delivery schedules. While increased speed limits have given carriers some additional flexibility in meeting demanding schedules, increased congestion and especially incidents make it much more difficult to adhere to these schedules.

### ***Drivers***

The potential for rising factor prices (e.g., fuel, materials, labor) is a threat to further productivity improvements. The ability to obtain, train, and retain truck drivers is a major concern to motor carriers, as discussed in a related theme paper in this series, *Economy: Rapid Change in Manufacturing and Service Sectors*. According to one motor carrier executive, “the quality and availability of drivers is very much of a problem and this problem is intimately bound up with service performance.” Insurance costs are another problem, especially for small carriers. The same trucking industry executive observes: “the twin forces of higher and even unavailable insurance plus higher fuel prices are destroying profitability.” This latter concern was echoed by other motor carriers that fear that U.S. Environmental Protection Agency (EPA) mandates for emissions control will reduce fuel efficiency and increase fuel costs.

### ***Vehicle Technology***

Trends in vehicle technology may provide grounds for carrier optimism. Continued advances in vehicle technology may lead to lighter, more fuel-efficient vehicles that can carry somewhat heavier payloads under current truck size and weight constraints. Information systems may continue to provide greater ability to avoid incidents or bottlenecks. However, this is the case only if the system has enough redundancy to provide for other route choices.

## **Water Carrier and Port Productivity**

According to National Transportation Statistics, the inland waterway system moves 650 million tons of primarily bulk freight at low rates. These commodities would otherwise have to move on highways and railways at higher costs. From a barge company’s perspective, the primary concern is not so much to seek productivity improvements, but simply to maintain and retain the current system.

Much of the nation’s inland waterway infrastructure is aging, with many of its locks more than 50 years old and beyond their design life. A huge backlog of rehabilitation and maintenance projects exists, and enhancements are needed to update the system. Renewal of the system infrastructure will be a major concern over the next 20 years. Planning and rehabilitating will be complex tasks, because there is greater concern for environmental issues than when the system was originally built.

Labor productivity remains an issue in marine transportation. On the West Coast, union work rules limit the hours for port operation. Hence, opportunities exist for achieving further productivity improvement through contract negotiations.

## **Air Carrier Productivity**

Dedicated air carriers have developed highly efficient hub and spoke operations, and make intensive use of technologies for tracking time-sensitive shipments. While the dedicated carriers have been able to locate their hubs in airports with the capacity to handle their flights and ground operations, the need exists for connections to other airports that have capacity problems in terms both of landings and takeoffs and of space for freight facilities. Internationally, non-dedicated airfreight moves primarily in wide-body passenger jets with capacities on the order of 100,000 pounds of freight. Productivity gains for airfreight using non-dedicated aircraft are limited by the capacity constraints impacting upon overall air travel today. Further growth in productivity for airfreight almost certainly will require enhancements to physical and operational capacities through capital investment in either traditional facilities such as runways or investments in IT.

## **Information Technology and Productivity**

Both customers and carriers have developed high expectations for new technology, especially information technology (IT) and intelligent transportation systems (ITS), and these expectations likely will grow in the future. In the private sector, IT and ITS technologies are expected to improve scheduling, routing, dispatching, shipment tracing, and terminal management. In the public sector, they are expected to help with highway and traffic management and streamlined permitting. While there are opportunities to utilize IT to a much greater extent, there are also constraints. IT requires capital and operating resources, and there may continue to be a shortage of skilled IT labor. Transportation industries, whether public or private, have traditionally not provided compensation at the top range of pay scales, and this is a particular issue when many other industries are also seeking skilled IT labor.

The public sector may experiment with congestion pricing of bridges, tunnels, roadways, and parking as a traffic management technique aimed at squeezing more efficiency out of the highway network. As knowledge of the importance of freight grows, more attention may focus on the location and accessibility of freight terminals and hubs in the broader planning and transportation planning process. Despite any potential of IT or other improvements to systems and services, substantial need for improvements to the physical capacity of freight systems will exist.

IT as an integrating technology was a prominent theme during interviews with Professors Joseph Sussman and Henry Marcus, both with the Massachusetts Institute of Technology Center for Transportation Studies. Sussman sees major opportunities for IT in commercial vehicle operations as states streamline their interface with truckers for routine interactions. Marcus observes: “All of the steamship companies are setting up logistics firms because they are paranoid about losing control of the customer and becoming subject to commoditization.” Both professors expect carriers to achieve efficiencies from fleet management, with a possibility that the technology will reward the better carriers and foster rationalization. Both suggest that there is a continuing need for federal research and development for transportation, as past federal R&D has provided the basis for many of the productivity improvements that have been achieved.

One motor carrier executive sees great potential in IT for shippers, who will be able to track shipments and manage inventories more effectively; at the same time, this executive questions how great the benefits will be in reducing costs for the carriers. While satellite communications have provided some operational gains, they have not been huge for the truckload carriers. The overall gains from tracking trailers may be greater than the gains from tracking tractors, but the shippers are likely to get the greatest benefits. Several carrier officials anticipate gaining considerable productivity from applications of IT and operations research to integrated supply chain management. Again, it ultimately is the customers, not the carriers, who stand to reap the greatest benefits.

ITS is providing public agencies new capabilities for monitoring and managing traffic flows. The use of ITS is clearly expected to help offset some of the congestion problems in major metropolitan areas.

An emerging area of ITS/IT technology application is to improve intermodal connection and intermodal asset management. The USDOT, through ITSA, has convened an Intermodal Freight Technology Working Group and conducted two national conferences on Intermodal Technology to assess potential for technology applications to intermodal freight. Several ITS operational tests are under way with public-private teams.

Carriers view IT as a way to work with customers to create ‘customized products with packaged information.’ Carriers and customers will be able to use timely, complete information to rationalize their traffic and operations. A rail official suggested that railroads should “become logistics providers, move heavily into information technology, and greatly simplify their operations.”

Barge companies use the global positioning system (GPS) and electronic charts and look forward to the installation of Vessel Traffic Systems in port. These systems will improve both capacity and safety. Carriers also use satellite communications to monitor position, engine performance, and other factors that will allow operating tradeoffs between speed and fuel costs.

Tables 1, 2, and 3 illustrate some potential future productivity improvements for highway, rail, and port freight facilities and services. These are illustrative ideas; no evaluation of potential actions is intended in this theme paper.

**Table 1. Highway/Truck Operations - Examples**

Operations Strategy	Problem	Solution	Examples
Corridor Traffic Information	Lack of corridor-scale congestion and routing information for truckers	Corridor and national travel condition information services targeted to truckers	I-95 coalition Fleet Forward (operations test); rural ATIS program; roadway weather information systems
Incident Management	Delays and	Proactive response to	Chicago Minuteman

<b>Operations Strategy</b>	<b>Problem</b>	<b>Solution</b>	<b>Examples</b>
	deteriorating reliability because of incidents (e.g., breakdowns, crashes, etc.)	incidents and traffic management to minimize backups; expertise in clearing heavy truck-involved incidents	Patrol
Work Zone Management	Delays and increased risk of accidents at work zones; truck prohibited from detour routes because of low bridge clearances, etc.	Specific attention to maintenance of truck flows at work zone and along diversion routes	
Automated Border and Weigh Station Clearance	Delays at ports of entry and weigh stations for regulatory and safety inspections	Automated credential and weight pre-clearance screening; coordination of customs, INS and DOT inspection functions	ITS/CVO program; CVISN

**Table 2. Rail Operations - Examples**

<b>Operations Strategy</b>	<b>Problem</b>	<b>Solution</b>	<b>Examples</b>
Increasing Rail Headway and Capacity	Complex interoperative systems are needed to safely operate freight trains at speeds greater than 79 mph	Positive train control	Research is underway
Interchangeable Domestic Container Pools Which Add to Speed and Service on Rail Lines	Equipment only available to one rail carrier is inefficient	Domestic interline container pools	EMP – participants are NS, UP, CP, KCS, Wisconsin Central, etc.  NACs – participants are BNSF, CN, CP, CSX, IMRL
Open Platforms for Rail Service Booking Adds to Customer Appeal and Adds to Velocity	Single carrier booking is time and labor intensive	Web-enabled communications for booking and tracking	ARZOOM members are US, CSX, NS, and CP

**Table 3. Port and Terminal Operations - Examples**

<b>Operations Strategy</b>	<b>Problem</b>	<b>Solution</b>	<b>Examples</b>
Remote Inland Ports/ Depots	Congested port terminals	Move empty containers to inland site	Virginia Port Authority’s inland terminal
Increase IT Capability/ Automation	Low terminal productivity and turn times	Increased information/ reservation system	Port of NY/NJ’s FIRST
Agile Port Technology	Need for increased port throughput	IT system integration between ship and train	USDOD agile port technology demonstrations

## ■ Issues in System Construction and Optimization

The nation's freight transportation system is mature, comprehensive, and relatively efficient. The challenge for the future is to maintain the capabilities of this system as demand increases. Although carriers' productivity improvements cannot be expected to continue at the pace of the past 20 years, some improvements can be achieved, especially through the application of information technology. Nevertheless, additional and substantial investments in highway and other transportation facilities will be needed in areas of high growth or congestion. The previous emphasis on system optimization has resulted in a rail freight system that has higher productivity but with no excess capacity and that lacks redundancy; a highway freight system in which costs have decreased and in which deregulation has eliminated many inefficiencies such as empty backhauls; an inland waterways system that moves bulk commodities at low cost; a hub-and-spoke airfreight system that moves high-value commodities quickly and efficiently at high cost; and an intermodal system that takes advantage of the attributes of the various modes. The systems individually and collectively represent a more optimized system than decades ago. A characteristic of an already optimized system is the need for major investments to increase capacity or quality of service since, by definition, there is no excess capacity or system redundancy left to exploit at low cost.

There are further important opportunities for intermodal and multi-modal integration and coordination. The nation's highways, railways, and waterways comprise a complex, effective system that supports freight mobility throughout the country. To the extent that the railways and waterways can move freight efficiently, the demand on the highway system will be reduced. There is a clear federal role for promoting the best use of each mode, encouraging intermodal coordination, and supporting comprehensive freight planning processes at the state and local levels. There is also a potential federal role for participating in or helping to finance public/private efforts to address bottlenecks in the system, including major freight bottlenecks such as the most congested Interstate segments, or the previously cited network of rail lines and terminals around Chicago. There is a strong national interest in maintaining ubiquitous, high-quality freight transportation capabilities and in continuing the longtime contributions of transportation productivity improvements to the national economy.

Below, some of the key issues are synthesized from interviews and assessments of the evolution of the nation's freight system.

### ***To What Extent Can Information Technology Reduce the Need for Expanded Transportation Infrastructure?***

IT offers great potential for optimizing the use of transportation facilities, through travel planning and scheduling, reservation systems, monitoring, and real-time control. All of the carriers who were interviewed mentioned the potential productivity improvements achievable from IT. The carriers and the customers both talked of the potential for IT to improve coordination throughout the supply chain, leading to increased productivity from smoothing traffic peaks, consolidating shipments, and matching supply and demand. However, concerns were expressed that IT alone cannot obviate the need for investment in alleviating the bottlenecks within the networks.

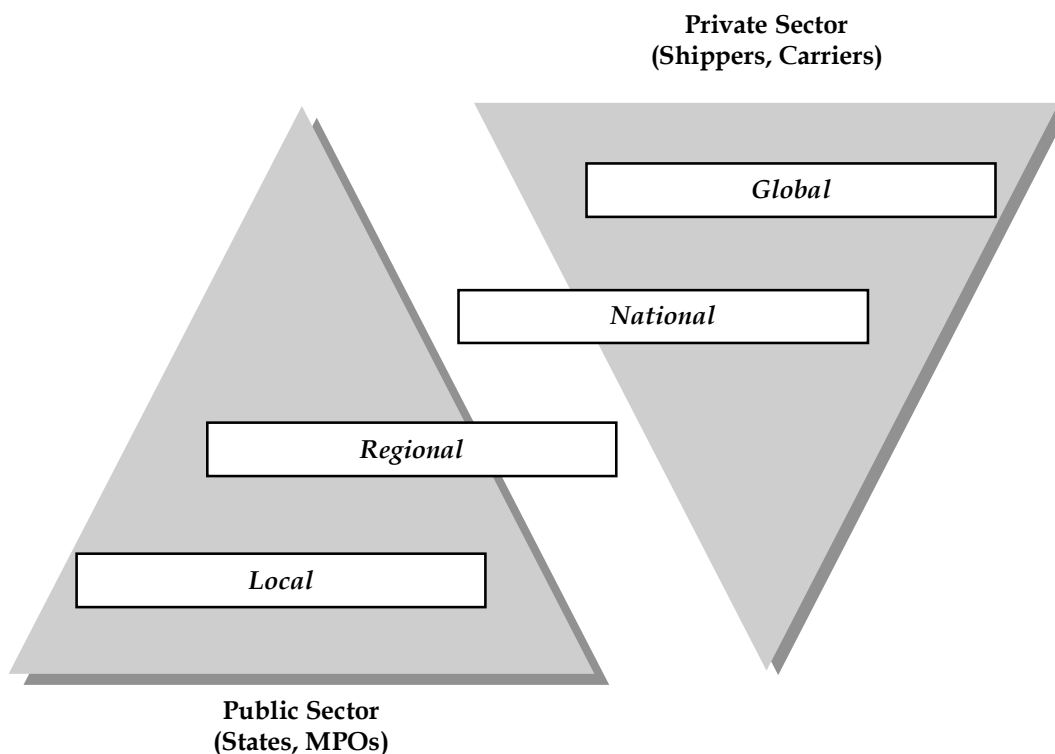
### *Will Future Gains from Technology Be as Great as Past Gains?*

Opportunities still exist for better vehicle design, improvements in labor productivity, and technological benefits from automation, better materials, and better components. However, these improvements are not likely to be as great as in the past, in an absolute sense, because of the remarkable economies already achieved.

### *How Will Freight Needs Be Represented in Public Infrastructure Investment Decisions?*

System optimization, much more so than system construction, is an ongoing process involving governments at all levels. Today, with more limited capital investments, the demand forecasts – and the interests of freight – need to be specified more accurately, as the consequences of being wrong are much higher. A basic institutional difficulty that must be addressed is the mismatch between the local focus of states and MPOs and the increasingly national and global focus of the major freight carriers and their customers (see Figure 4). Freight issues require more extensive multi-jurisdictional coordination than do most passenger issues.

**Figure 4. Freight Transportation Perspectives State and MPO Focus is Regional and Local; Private Sector Focus is Increasingly National and Global**



It will be appropriate to focus attention on infrastructure and planning strategies at the local and regional level that consider the needs of freight transportation in the same way that the needs of commuters are handled. The MPOs tasked with developing long-range

transportation plans and transportation improvement programs are not all aware of or expert in freight needs. The recent NHS intermodal connector report to Congress highlighted the need for increased awareness and coordination in the planning process, improved funding strategies, the application of technology, and finally the resolution of community and environmental issues.<sup>5</sup>

### ***System Optimization Does Not Mean That Capacity Investment Requirements Will Decline***

As traffic volume grows so does congestion, and bottlenecks in the system become more apparent. While improvements to the management of critical parts of the system and better vehicle and control technology can offer some relief, eventually investment will be required to expand the capacity of the system. Given that capacity will likely be needed in or near the most congested areas, the costs of these investments could be much higher, per mile, than the average costs of constructing the system initially.

The theme paper *Economy: Rapid Change in Manufacturing and Service Sectors*, which deals with the impact of economic changes on freight transportation, has a conclusion directly relevant to this issue:

*“The rising importance of the service economy will not diminish the need for traditional transportation services. Bulk transportation – by railway, waterway, highway, or pipeline – will continue to account for the great majority of freight transportation. Efficient movement of grain, coal, ores, and other bulk commodities will continue to be a basic requirement of the freight system and an underpinning of the national economy.”*<sup>6</sup>

### ***Intermodal Terminals Will Be A Focal Point for Public Concern***

Ports and intermodal terminals will be a major concern for public agencies interested in the freight transportation system. Intermodal transportation is expected to continue to grow rapidly, with benefits to the economy and to the public in terms of trade and the environment. However, the intermodal transport system depends upon sufficient terminal capacity, which is likely to become a constraint in many areas. Intermodal terminals require a great deal of land, they attract a stream of highway traffic, and they operate 24 hours per day. This combination of attributes makes it difficult for private companies to find suitable sites for new terminals or acceptable means of expanding existing terminals. Left to themselves, railroads will tend to locate new capacity well outside of major metropolitan areas, leaving long-drayage moves along the most congested highways for the initial pickup and ultimate delivery. Likewise, ocean carriers will tend to serve fewer ports, with longer inland movements by truck or rail.

These solutions, while possibly satisfactory to the carriers and some of their customers, fail to deliver the potential improvements in highway congestion, safety, and air quality

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<sup>5</sup>NHS *Intermodal Freight Connectors, Report to Congress*, U.S. Department of Transportation, July 2000, available at <http://www.ops.fhwa.dot.gov/freight/adfrmwrk/index.htm>.

<sup>6</sup>See related theme paper in this series, “*Economy: Rapid Change in Manufacturing and Service Sectors*.” Also see “*Transportation Policy: Evolution of Federal Freight Transportation Policy*,” available at <http://www.ops.fhwa.dot.gov/freight/adfrmwrk/index.htm>.

hoped for from increasing use of intermodal transportation. This suggests that intermodal terminal development is an area for public involvement. Terminal size, location, and access are matters that can best be addressed in the context of metropolitan land use, local development issues, and strategic plans for regional transportation systems.

### ***Competition Leads to Lower Prices – But May Reduce the Robustness of the Freight System***

Deregulation has played an important role in promoting an efficient, productive transportation system. Widely believed to be responsible for declining freight rates over the past 20 years, deregulation has also led to a system that is quite different from the regulated system it replaced. The current system is more productive, less costly, and more flexible in terms of the variety of services that are offered. However, the regulated system was more robust, in that it supported a higher level of capacity relative to demand, and provided for redundancy in terms of the facilities and services available. Part of the productivity achievements represents a deliberate reduction in system redundancies and buffer capacities. With better utilization comes higher productivity, but there is also a loss in terms of robustness. Through lower prices, customers and the public have been the major beneficiaries of increased efficiency within the system – but they also bear the brunt of the service problems when the system breaks down, as has happened recently for periods of time after recent rail mergers.

The public interest may be served by taking steps to ensure that the efficiencies created through deregulation do not create a system that is too fragile, with too little reserve capacity to respond to unexpected events or to rapid growth in demand. Some amount of slack is desirable to assure that services can be maintained. However, the question is how much reserve capacity and system redundancy is desirable and at what cost to public agencies, carriers, and shippers.

### ***New Freight Systems Could Emerge***

Although none of the stakeholders interviewed mentioned completely new freight systems, the possibility exists that new systems could emerge in the same way that new air and express package systems blossomed in recent decades. For example, there have been some studies of “tube transport systems,” in which automated vehicles travel along a network in tunnels below a city.<sup>7</sup> Instances of specialized freight handling services (e.g., loading docks and freight elevators for large buildings or the remote and automated baggage systems used in airports) could be expanded over a larger area. Separating some shipments from the urban street network would be a way to avoid the most congested areas.

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<sup>7</sup>Tube transport is not a fanciful idea. At the turn of the 20<sup>th</sup> century, pneumatic tube systems were in widespread use in cities throughout the U.S. Under the streets of Manhattan, a 55-mile network connected 21 post offices to the main branch office. Canisters of mail carrying up to 500 letters moved at 30-mph speeds down to Wall Street and up to 125<sup>th</sup> Street. Paris’ 269-mile system was not abandoned until 1983.

### ***Intermodal Cooperation Could Lead to Innovations in Intermodal Technology***

New designs for vehicles and terminals could promote more effective intermodal and carrier/customer partnerships. A good example is the distribution of new automobiles, where both railways and motor carriers use specially designed equipment and terminals to serve this major freight market.

More ambitious innovations can be imagined. For example, railroads can readily transport wider and heavier containers than are allowed on the nation's highway system. Is it possible to establish access roads to major intermodal terminals that could accommodate wider and heavier trailers and containers, thereby allowing efficiencies in drayage, terminal handling, and line-haul operations? Undoubtedly, but only with a major public involvement and a willingness to consider applying different size-and-weight limits to a limited subset of highway segments. Another possibility would be to use rail corridors as toll routes for trucks where rail corridors might be suitable for dual use during certain portions of the day.

### ***The Challenge Exists...***

There are parallel threats to freight improvements due to other concerns. Pressures may mount to restrict freight operations for reasons such as enhancing highway or rail passenger services, improving safety, or reducing freight impacts on sensitive areas or low-income communities. It is desirable to incorporate freight issues and opportunities more fully into all transportation planning and decision-making. Whether actions are aimed at system construction or at system optimization, full coordination of public and private actions will be necessary to assure that the most effective and desirable enhancements are identified and implemented. Since freight concerns span a wider geography than urban areas, enhanced and wider forums are needed for coordinated system construction and system optimization strategies.