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TECHNICAL
REPORT

The State of U.S. Railroads

A Review of Capacity and Performance Data

Brian A. Weatherford, Henry H. Willis, David S. Ortiz

Supported by the UPS Foundation

RAND Supply Chain Policy Center

A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT CENTER

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Preface

Concern about the ability of the U.S. railroad system to accommodate a significant increase in rail freight volume without degrading the speed and reliability of railroad service has motivated several recent studies of railroad infrastructure. Many of these studies were commissioned by trade associations or organizations representing interested parties, and it is challenging to disentangle facts about the current capacity and performance of railroads from advocacy positions of carriers or shippers. This report draws from publicly available data on the U.S. railroad industry to provide observations about rail infrastructure capacity and performance in transporting freight.

This report should be of interest to freight carriers, shipping companies, congressional and executive-branch leaders responsible for establishing transportation policies and priorities, and other organizations concerned about the capacity and performance of railroads.

The research and analysis presented in this report are based and expand on prior RAND Corporation work on current policy issues in transportation and the supply chain. The interested reader may wish to refer to the following publications for more detail:

- *Increasing the Capacity of Freight Transportation: U.S. and Canadian Perspectives* (Ortiz et al., 2007)
- *Evaluating the Security of the Global Containerized Supply Chain* (Willis and Ortiz, 2004).

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The RAND Transportation, Space, and Technology Program

This research was conducted under the auspices of the RAND Supply Chain Policy Center (SCPC) of the Transportation, Space, and Technology (TST) Program within RAND Infrastructure, Safety, and Environment (ISE). The mission of 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 in their workplaces and communities. The TST research portfolio encompasses policy areas including transportation systems, space exploration, information and telecommunication technologies, nano- and biotechnologies, and other aspects of science and technology policy.

As part of this effort, RAND has established SCPC to conduct research that helps the public and private sectors address critical issues in freight transportation. The center is funded by contributions and derives its strength from the RAND Corporation's 60 years of interdisciplinary experience addressing policy issues of global importance through objective and independent analysis.

Questions or comments about this report should be sent to the project leader, Henry H. Willis (Henry_Willis@rand.org). Information about TST is available online (http://www.rand.org/ise/tech). Inquiries about SCPC, its research, or publications should be sent to the following address:

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Contents

Figures

Tables

Summary

U.S. freight volumes are expected to double in the next 30 years. Increased use of rail freight is seen as a way to accommodate increased volumes while minimizing congestion on the highway system. However, the U.S. railroad network consists of many fewer track miles than it did several decades ago, and there is concern that it has become congested and incapable of handling additional volume.

Concern about the ability of the U.S. railroad system to accommodate a significant increase in rail freight volume without degrading the speed and reliability of railroad service has motivated several recent studies of railroad infrastructure. Many of these studies were commissioned by trade associations or organizations representing interested parties, and it is challenging to disentangle facts about the current capacity and performance of railroads from advocacy positions of carriers or shippers. This report draws from publicly available data on the U.S. railroad industry to provide observations about rail infrastructure capacity and performance in transporting freight.

Railroad capacity is determined by many factors, including the amount of railroad track and rolling stock, the number and power of locomotives, maintenance, staffing levels, and a wide variety of operating strategies. Increases in railroad productivity over the past quarter-century indicate that more freight (as measured in ton-miles) is being transported today than ever before. Data suggest that this has been made possible by increasing the utilization of railroad infrastructure through technological innovation and improved operations. However, analyzing trends using the single metric of capacity fails to capture the complexity of rail performance.

Speed and reliability are the most salient metrics of the performance of rail service. Long-term trends show improvements in both of these measures. However, publicly available data suggest that these decade-long trends may be slowing or reversing. Some shippers suggest that this is the case and that, in certain markets or regions, they are experiencing significantly higher costs or poorer performance from freight rail service. However, data are not shared publicly at the temporal, geographic, and commodity levels to assess these claims. Thus, it is not apparent whether performance is now stable, significantly declining, or improving.

One reason to examine the impacts of railroads performance on freight markets is that these markets are determined by the collective decisions of carriers from multiple modes and shippers of multiple types of freight.[1] In addition to the rates charged by a trucking or railroad company to transport its freight, the shipper must consider the amount of time it will take for its goods to arrive at the correct destinations; the risk that its freight might get damaged,

1 In this report, we use *mode* to differentiate types of freight transportation: Rail is one mode; trucking another.

lost, or delayed; and other costs, such as paperwork, warehousing, and drayage. Railroads and trucking companies take actions that influence the overall cost of shipping freight, and shippers respond to these signals. Thus, when a railroad or trucking firm improves performance, shippers may respond by shifting the transportation of freight—even extremely time-sensitive shipments—from one mode to the other.

As an illustrative example of this issue, this report describes how slower and less reliable shipments led one firm to shift traffic from rail to truck to fulfill its customers' orders in a timely manner and maintain its supply chains at the lowest overall cost. This example illustrates the larger, public consequences of private decisions to shift freight transportation among modes. Shippers make transportation decisions based on what modes of transportation best satisfy their firm's logistics supply chain. Their decisions, however, have consequences that affect other users of the transportation system, communities through which the infrastructure passes, and the environment, because different modes of freight differ in their safety concerns, levels of pollution, and energy consumption. These interactions justify an expanded public-sector role for freight transportation planning.

Based on these observations, this report raises three issues for additional analysis to create options for transportation policy and support transportation planning:

- *Improved reporting and public dissemination of railroad system and performance statistics are needed to support transportation policy.* Far more data are available for highways than for railroads, which are no less critical to the efficient flow of goods. Analysis of freight transportation planning in general and railroad transportation planning in particular is hindered by a lack of publicly available, detailed, and accurate data. Better data allow for practical incentive-based policies to set rail performance standards.
- *The public and private cost trade-offs between shipping freight by truck and by rail need to be better understood.* Far too little is known about this important issue at this time to recommend major policy changes, but the implications are potentially large, especially as the highway system becomes increasingly congested and rail rates continue to rise. Future research should include developing a more accurate comparison of rail and truck freight transportation costs and a model that can be used to explore different policy options, such as congestion tolls, carbon taxes, and the proposed rail infrastructure tax credit. Capturing the relative congestion externalities will require developing improved economic modeling of decisionmaking in the freight transport industry as well as large-scale modeling of the nation's multimodal transportation network.
- *A national freight strategy should balance the private interests of the shippers and railroads with the public interest associated with the public costs of different modes of transportation.* By passing the Staggers Rail Act (P.L. 96-448), the government did not abdicate responsibility for overseeing the railroad industry. Surface-transportation advocates appear to agree that some federal coordination and possibly funding of rail capacity expansion will be necessary, but it is the federal government's responsibility to ensure that this investment benefits the public interest.

Acknowledgments

This work was supported by the UPS Foundation and benefited from consultations with the advisory board of the RAND Supply Chain Policy Center. The authors also wish to thank RAND colleagues in the Supply Chain Policy Center for their added insights and contributions to this study, including Thomas Light, Kate O'Neal, Paul Sorensen, and Martin Wachs.

Abbreviations

AAR	Association of American Railroads
ABS	automatic block signaling
BNSF	Burlington Northern Santa Fe Railway
CAPM	capital-asset pricing model
CN	Canadian National
CP	Canadian Pacific Railway
CPI	consumer price index
CTC	centralized traffic control
DOT	U.S. Department of Transportation
FRA	U.S. Federal Railroad Administration
GDP	gross domestic product
KCS	Kansas City Southern
NS	Norfolk Southern
PTC	positive train control
SCTG	Standard Classification of Transported Goods
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Code
UPS	United Parcel Service
VMT	vehicle miles traveled

CHAPTER ONE

Introduction

The Federal Highway Administration has projected that U.S. freight tonnage will grow by more than 70 percent between 2006 and 2035 (FHWA, 2007, p. 11, Table 2-1). Transportation officials view an increased use of rail freight as a way to accommodate increased volumes without adding more trucks to the congested U.S. highway system. However, the U.S. railroad network consists of many fewer track miles than it did several decades ago, and shippers and policymakers are concerned that it has become congested and incapable of handling additional volume.

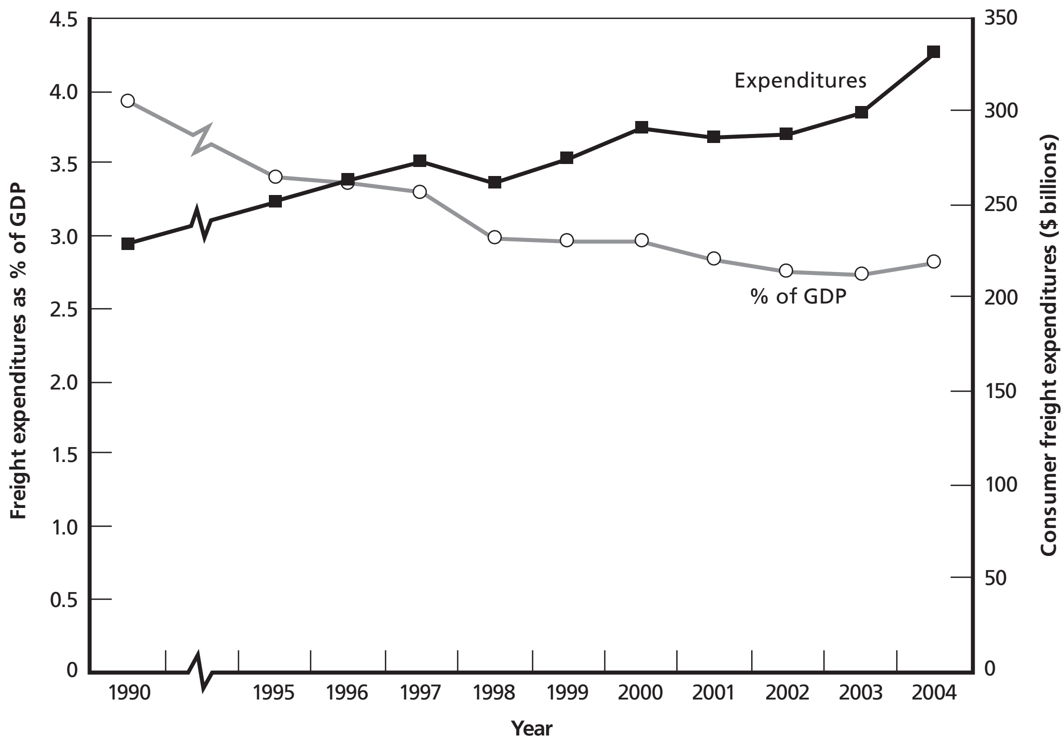
Concern about the ability of the U.S. railroad system to accommodate a significant increase in rail freight volume without degrading the speed and reliability of railroad service has motivated several recent studies of railroad infrastructure (see Cambridge Systematics and Association of American Railroads, 2007, and AASHTO and Cambridge Systematics, 2003). Many of these studies were sponsored by trade associations or organizations representing interested parties, and it is challenging to disentangle the facts about the current capacity and performance of railroads from advocacy positions of carriers or shippers. This report draws from publicly available data on the U.S. railroad industry to provide observations about rail infrastructure capacity and performance in transporting freight drawn.

Freight Transportation: An Engine for Economic Growth

For decades, the U.S. economy has benefited from declining transportation costs. With the introduction of containerization, manufacturers and retailers took advantage of cheaper and more-reliable transportation to reduce inventories and implement just-in-time operating practices. Lower inventories made additional capital available to be reinvested or returned to shareholders and contributed to economic growth. After steadily falling for several decades, U.S. transportation and logistics spending, normalized against gross domestic product (GDP), started to increase in 2004. Between 1990 and 2003, the ratio of spending on freight transportation to GDP fell from 3.92 percent to 2.72 percent. In 2004, as shown in Figure 1.1, this ratio increased moderately (Eno and UGPTI, 2007). According to the *18th Annual State of Logistics Report®*, the upward trend in transportation and logistics costs that began in 2004 continued in 2005 and 2006 (Wilson, 2007, p. 1).

Many factors are responsible for the relative (and nominal) increase in logistics costs, including truck-driver shortages, rising fuel prices, higher interest rates, increased inventories to counter decreased shipment reliability, and higher freight shipping rates (Wilson, 2007,

Figure 1.1
Total Freight Expenditures in Billions of Dollars and Percentage of GDP (1990–2004)



SOURCE: Eno and UGPTI (2007, p. 32).
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pp. 6–9). As transportation becomes more expensive and less reliable, this trend toward higher logistics costs is expected to continue (Ortiz et al., 2007, p. 8; Wilson, 2007, p. 14).

Given the economies of scale in railroad operations and concerns over highway congestion, rail freight is seen as part of the solution to increased logistics costs. Many of the largest shippers optimize their logistics systems by shipping some of their inventory by rail. Local policymakers in Los Angeles (and elsewhere) are looking at short-haul railroad "shuttle services" as a solution to urban traffic congestion (SCAG, 2005, p. 18). In addition, H.R. 1300 (U.S. House of Representatives, 2007) mentions "bolstering rail infrastructure" as one way to reduce the nation's dependence on foreign oil because rail transportation is more fuel efficient than trucks are over long distances. Rail's ability to contribute to future freight capacity depends on maintaining or improving the capacity, speed, and reliability of the national railroad network.

The Pressures of Increased Demand for Transportation

The U.S. transportation network is operating at an unprecedented level of traffic density. As shown in Table 1.1, the density of traffic on the highway system has more than doubled over the past 25 years. One consequence has been the costs of chronic urban traffic congestion. The Schrank and Lomax (2007, p. 8) calculated that, in 2005, traffic congestion wasted 2.9 billion gallons of fuel and 4.2 billion hours of highway users' time.

Table 1.1
Traffic Density

Year	VMT per Highway Lane Mile (millions)	Ton-Miles per Track Mile (millions)
1980	1.65	3.40
1985	1.96	3.62
1990	2.42	5.17
1991	2.46	5.30
1992	2.53	5.60
1993	2.61	5.95
1994	2.70	6.54
1995	2.78	7.24
1996	2.76	7.66
1997	2.94	7.82
1998	3.04	8.05
1999	3.11	8.48
2000	3.18	8.70
2001	3.23	8.94
2002	3.29	8.86
2003	3.35	9.18
2004	3.43	9.94
2005	3.45	10.33

SOURCES: VMT per lane mile: staff calculations using data from U.S. Federal Highway Administration (all dates). Ton-miles per track mile: AAR (2006, p. 42).

NOTE: VMT = vehicle miles traveled.

Over the same time period, railroad network traffic density has nearly tripled. Increased rail productivity, also shown in Table 1.1, has generated higher returns on capital but has also raised concerns that railroad speed and reliability will fall as volumes continue to increase without investments in additional infrastructure.[1] If rail service performance were to decline under the pressure of increasing traffic density, rail would become a less effective mode for transporting freight. Furthermore, the resulting increased utilization of trucks would exert additional congestion costs on the U.S. economy as well as additional environmental costs. These concerns about the capacity of rail to accommodate growth in freight demand present a dilemma for advocates of rail freight as a potential solution to highway traffic congestion.

1 See Cambridge Systematics and AAR (2007), which calculates railroad infrastructure needs based on a volume-to-capacity ratio calculation.

Concerns About Rail Infrastructure

The broad economic importance of logistics systems and their impacts on transportation networks raise questions about railroad infrastructure and systems that concern shippers, regulators, and policymakers. First, is the performance of rail infrastructure decreasing? Second, how are shippers responding to changes in rail performance? Third, is there justification for public-sector involvement in rail infrastructure planning and financing?

Defining and measuring rail performance is challenging and complex. Through changes in operations, productivity, and pricing policies, the railroads have been able to increase the amount of freight shipped while making limited new investments in infrastructure. While rail carriers have adjusted their operations to increase capacity, they have not consistently improved speed and reliability. Rail transportation has become more competitive with truck transportation, but service speed and reliability remain too low for many classes of freight. Rail traffic density may continue to increase, allowing for further productivity improvements, but recent indications that rates are rising suggest that it is possible that, at least in the near future, rail volumes may be approaching capacity. Publicly available data do not indicate that that has yet happened, but there are physical limits on rail capacity and to productivity improvements, and the possibility of reaching those limits raises concerns that the quality of rail service will decline.

At recent government hearings, shippers from agriculture, coal, chemicals, and other bulk-commodity industries expressed their dissatisfaction with what they perceive to be a decline in the quality of railroad service and "monopolistic" rates.[2] As a result, shippers have called for "new approaches to rate regulation" and, thus, reconsideration of the Staggers Rail Act (P.L. 96-448; see Whiteside, 2005, p. 3).

That statute partially deregulated the railroad industry and gave railroads greater flexibility to set rates and optimize their networks. In the years following the passage of the Staggers Rail Act (P.L. 96-448), the railroads merged their operations, sold off underperforming routes, and cut rates to their largest customers as they worked to stimulate demand.

Shippers, especially small agricultural producers, have loudly protested that the actions of the rail industry since the passage of Staggers have led to higher rates and poorer service. However, the many studies conducted by academia, government, and industry show that the net effect of rail deregulation was to reduce rates for all commodities, increase competition, and improve factor (e.g., labor, capital) productivity.[3] These studies have shown that large shippers able to fill multiple rail cars per shipment have fared better under the new regulatory environment than have small shippers.

The Staggers Rail Act (P.L. 96-448) is widely credited with allowing the industry to recover financially after a sustained period of bankruptcies and falling revenues (Winston, 2005). However, many of those studies are now several years old, and more-current research from the finance industry suggests that rail rates have begun to increase by as much as 30 percent for some customers (Greene, 2007, p. 5). Despite vocal complaints to Congress and the

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[2] Many shippers have expressed concern about the cost and performance of rail service; for example, see witness testimony from U.S. House of Representatives (2006), U.S. Senate (2006), and oral-argument exhibits from STB (2005, 2007a, 2007b).

[3] For example, see Bitzan and Keeler (2003), Brown (1998), Davis and Wilson (2003), MacDonald and Cavalluzo, (1996), Martland (2006), and Winston (2005).

Surface Transportation Board (STB), it appears that most shippers have access to transportation markets that function reasonably well and allow them to choose, based on costs and performance, transportation services that best serve their interests.[4]

Shippers, even within the same industry, differ from one another in their distance to suppliers and markets and their access to transportation infrastructure. As railroads changed rates and consolidated track, the effects of those changes on shippers benefited some more than others, and some shippers may have ultimately been hurt by those changes. Captive shippers, those who have limited transportation options other than by a single rail carrier, have likely been hurt by the rate changes and track consolidations that followed deregulation. Their competitors, which retained access to multiple carriers because of the locations of their facilities or their suppliers, likely benefited from the same changes.[5] In contrast, intermodal shippers can balance cost and performance of freight transportation by selecting among competing rail and truck freight services.[6]

In principle, some freight transportation markets are efficient because intermodal shippers using trucks are able to shift to rail if it would serve them better and shippers using rail can shift to truck if rail is not serving them well. Thus, it is possible that any additional costs to further improve the speed and reliability of rail service would increase rates above levels that shippers would pay. Accordingly, it is only rational for railroads to improve performance if the additional amount they can charge exceeds the marginal cost of improved speed and reliability.

Some large businesses have, in fact, worked with railroads to reduce their transportation costs while maintaining a desired level of performance. The example of one company in particular, United Parcel Service (UPS), is illustrative of the challenges of increasing rail performance and the choices that private firms make in response. It also provides context for our third research question because it demonstrates the public impacts of private decisions to transfer freight from one mode of transportation to another.

The Public Costs of Private Logistics Decisions

In July 2003, the *Wall Street Journal* reported that CSX Corporation and Union Pacific had begun running trains between New York and Los Angeles in only 63 hours (Machalaba and Chipello, 2003). Using this service enabled UPS to cut the time for ground deliveries nationwide from five business days to four without raising prices. UPS officially announced the new service in October 2003:

> As part of a continuing effort to improve customer service, UPS has completed a major upgrade of its U.S. ground distribution network, reducing the time it takes for hundreds of thousands of packages to arrive at their destination every day.

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[4] The Surface Transportation Board resolves railroad rate and service disputes and reviews proposed railroad mergers.

[5] The captive-shipper problem is a market failure; however, it is not entirely clear how large a problem it is. The upper bound for rates remains regulated, and, because no bulk-commodity shipper can truck its product to an intermodal terminal, it is unclear how many actually do have access to multiple carriers.

[6] *Intermodal freight* refers specifically to a container or trailer on flatcar. Technically, containers are multimodal, since they may travel by ship and truck as well.

> The changes, implemented over the past four months, amount to the largest time-in-transit improvement effort since 1998 when UPS became the first carrier to offer money-back guarantees on its ground service. Each modification has slashed a full day off the previous guaranteed delivery time without any change in customer rates or pick-up and delivery hours.
>
> Shipments from Los Angeles to New York and vice versa, for example, now are guaranteed to arrive in four business days instead of five. . . . Some of the improvements, such as the four-day coast-to-coast delivery standard, were made in part through changes in railroad service. (UPS, 2003)

This new service positioned rail as a viable alternative to trucks for high-value, time-sensitive freight. However, to maintain the high performance required by UPS to meet its tight schedules, other freight trains were held on sidings to allow the high-speed trains to pass without needing to slow down. On some sections of the Union Pacific route between Los Angeles and El Paso, other trains had to be held on sidings for hours (Phillips, 2004). This reduced the average speed, sometimes referred to in the industry as *velocity*, on two of Union Pacific's busiest corridors. Union Pacific's operating costs increased because the falling velocity reduced the productivity of the available crews and the rolling stock. In some cases, crews had to be replaced before they reached their destinations because of rules limiting the number of hours they could work. Because locomotives and cars sat idle on sidings, they were unavailable to move the freight stacking up at rail yards around the country.

While the new service allowed CSX and Union Pacific to improve performance for UPS, the resulting delays and disruptions degraded service provided to other customers. In addition, this "hot-train" service began to exacerbate other operational problems—driven by changes in labor policies, increasing fuel prices, and surging demand from bulk-freight shippers—that had been troubling Union Pacific that year. These problems came to a head in March 2004. News articles in the *New York Times* and the *Wall Street Journal* cited the high-speed, transcontinental service for UPS as a confounding factor (Phillips, 2004; Machalaba, 2004). At the beginning of April 2004, the railroad decided to cease running the high-speed trains, and some UPS shipments were shifted back onto trucks (Ruff, 2004).

This example illustrates two important themes. The first is that railroad capacity constraints—resulting from trains running at different speeds and limited track, cars and locomotives, and crews—may lead firms to shift freight among modes. Because of capacity constraints, Union Pacific could not sustain the level of performance that UPS required, and some of its long-haul freight was shifted back onto highways in response. The actions described in this example resulted from private decisions that mutually benefited UPS and Union Pacific.

The second theme is that those private decisions have public costs. When UPS and Union Pacific decided to shift those many truckloads of parcels and packages from highway to rail, they were also reducing traffic accidents, air pollution, and congestion. These factors did not likely enter into the firms' calculations, although Union Pacific ultimately took account of the rail congestion resulting from running high-speed trains on the same track as its slower trains. Since the difference in the public costs of different modes of transportation is not reflected in the rates charged to customers, those costs do not influence the mode choices that shippers make. Over the long distance between Los Angeles and Chicago, railroads are more fuel efficient than trucks and do not impose costs on other highway users.[7]

The public costs of railroads are not always lower than those for trucks. Railroads impose other social costs, such as accidents at grade crossings and in rail yards. Trains also emit pollution, and they are noisy. The social costs of trucks and railroads are different. Quantifying that gap is challenging because many factors influence these relative costs, including the distance and grade of the route, travel speed, cargo weight, and the amount of time that the truck or train is idling. A 2001 study carefully compared the social costs of transporting a ton-mile of freight by truck and by an intermodal train (see Table 1.2) (Forkenbrock, 2001).[8] While there are limitations to how the findings of that study should be used, they are appropriate for calculating the social costs incurred when Union Pacific ended the high-speed service for UPS.

Assuming that each train hauls an average of 90 UPS trailers and that each load weighs 20 tons for a total of 1,800 tons per train and that the highway distance between Los Angeles and Chicago is just over 2,000 miles, each day that a shipment is diverted from rail an additional 3.6 million ton-miles is shifted onto the nation's highways. The total social cost of hauling a ton-mile of freight by truck is $0.012, $0.0084 more than by intermodal train. If these values and assumptions are reasonable, then every UPS trailer hauled by truck instead of by train imposes a social cost of approximately $340. If only one train is diverted per week, the additional annual social cost exceeds $1.5 million. This amount excludes congestion costs. Congestion costs are the value of the delay that an additional truck imposes on all of the other drivers sharing a highway. Railroads also create congestion at grade crossings.[9] Additional information and modeling are required to calculate the congestion cost externality. It is plausible that the

Table 1.2
Summary of Truck and Rail Freight Costs (2007 cents per ton-mile)

		Social Costs Excluding Congestion				
Type	**Private Cost**	**Accidents**	**Air Pollution**	**Greenhouse Gases**	**Noise**	**Total Social Cost**
General freight truck	11.69	0.82	0.11	0.21	0.06	1.20
Trains						
Heavy-unit	1.65	0.24	0.01	0.03	0.06	0.34
Mixed	1.67	0.24	0.01	0.03	0.06	0.34
Intermodal	3.72	0.24	0.03	0.03	0.06	0.36
Double-stack	1.47	0.24	0.01	0.03	0.06	0.34

SOURCE: Forkenbrock (2001, p. 334).

NOTE: We adjusted the values from 1994 dollars using the consumer price index (CPI). Total social costs differ slightly from row totals due to rounding.

7 In terms of traffic congestion and accidents.

8 An intermodal train carries intermodal containers and truck trailers on flatcars.

9 An additional train will likely delay other trains. This is different, however, because the railroad internalizes those costs in its operational decisions. Highway congestion is an externality because the driver of a truck or another car does not internalize the cost of the delay that he or she causes all the other drivers.

full cost of congestion over a year, when aggregated over the entire route, could exceed all the other social costs.

There is a great deal of uncertainty surrounding these numbers, and they should be used with care. The study on which they are based cites research conducted in the early 1990s, so more-recent research will probably value air pollution, accidents, noise, and greenhouse-gas emissions differently. More importantly, there have been changes in public policy and technological advances that have likely had impacts on both the magnitude of the external costs of trucks and trains and the difference in their costs. An examination of these costs individually shows that the magnitude of the accident-cost figure for both modes of travel far outweighs the other categories of external cost; accidents account for 69 percent of the total social cost. Per ton-mile, the social cost of freight-truck accidents is four times as high as train accidents. This suggests that even the values for the other externalities changing dramatically would not likely change the underlying conclusion: Intermodal trains traveling long distances have social advantages over freight trucks traveling between the same regions.

The social cost of mode shifting illustrated by this example motivates our third research question. Public interest may not be well served by the current state of the railroads and by transportation markets in general, because private markets fail to account for the social costs of transportation. Therefore, carriers provide, and shippers demand, socially inefficient volumes of transportation. If these costs were to be internalized, freight transportation rates for different modes would change relative to one another, and shippers would make decisions reflecting the full costs of transportation.

Content of This Report

Questions about the performance of freight infrastructure and the full social costs that result from changes in railroad performance are not being addressed in public discourse, despite the implications for the American public and the economy. To build a foundation for understanding and addressing these questions, the following chapters of this report review publicly available data describing the current state of the railroad industry.

Chapter Two disaggregates the components that jointly describe rail capacity to more deeply understand the ways in which capacity can be increased. By analyzing historical data on infrastructure, technology, operating strategies, and maintenance, this chapter concludes that track mileage is certainly important but is only one factor of capacity. Railroads can also adjust their operating practices to expand capacity, but this has implications for rates and performance.

Chapter Three reviews available data on rail performance. Rail performance is defined according to metrics important to shippers: speed, reliability, and cost. The resilience of the railroad system, which is particularly important for a transportation system with limited excess capacity and fixed routes of travel, is also considered. An analysis of available data does not provide a clear picture of railroad performance. Available data suggest that increased traffic density does not appear to have significantly hurt performance yet. However, these data are available only at an aggregate level, and more-appropriate data that describe performance by commodity, region, and carrier over time are typically proprietary.

Chapter Four summarizes the general observations of this study and presents three recommendations to policymakers to improve the performance of rail and ensure that adequate capacity exists to accommodate future freight volumes.

CHAPTER TWO

Capacity

The capacity of the rail network is determined by several parameters that span the physical and operational components of the rail system. To our knowledge, no universally accepted definition of rail capacity exists, but measures of capacity should be tied to the volume of freight that can be moved over a period of time across a certain distance. While track miles measure the extent of the rail system and motive power measures the ultimate amount of freight that can be moved, these measures do not indicate the productivity of these resources. James McClellan (2007, p. 32), a rail industry consultant formerly of Norfolk Southern (NS), said that rail capacity is determined by four interrelated factors: infrastructure, motive power, operating strategies, and crews. To this, we add industry structure as a factor. This chapter discusses the current trends in each of these factors that together form an understanding of rail capacity.

Capacity: Industry Structure

Early in the 1900s, the railroad industry suffered not from capacity constraints but from the opposite problem: excess capacity (McClellan, 2007, p. 32). Railroads lost market share as highways, air travel, and freight trucking competed with rail for intercity freight and passengers. Many freight shippers found it more economical to transport their goods by truck or air rather than by rail, and rail's share of the intercity freight-transportation market (measured in ton-miles) fell from 75 percent in 1929 to 44 percent in 1960 (AAR, 2006, p. 32).[1] The introduction of these new modes and associated innovations in logistics led to continued erosion of market share and falling railroad operating incomes (Eno and UGPTI, 2007, p. 40). Figure 2.1 shows net railroad operating income, consisting of operating revenues less the sum of operating expenses, for the period 1955 to 2005. This figure illustrates why some transportation experts consider the 1960s and 1970s to have been "difficult" (Stover, 1997, pp. 226–244). It was a period during which operating incomes were falling and several railroads went bankrupt. The industry and the federal government responded with organizational and regulatory reforms, beginning in the late 1970s, that led to major changes in the structure of the railroad industry (GAO, 2006; Winston, 2005).

Rail lost market share for several reasons. One is that trucks allowed shippers to make more-flexible industrial-location decisions and minimize total costs by relocating facilities away from railroad sidings to reduce facility costs and improve access to lower-cost labor. Another is

[1] The statistics are measured in ton-miles, which includes distance. Railroads carry only 15 percent of total freight tonnage between cities and, very likely, a negligible amount of freight within cities. Bryan, Weisbrod, and Martland (2007, p. 7), however, noted that "high volume moves of sand & gravel, road salt, or coal products are the major exceptions."

Figure 2.1
Real Net Railroad Operating Income (1955–2005)

SOURCE: Based on data from AAR (2006, p. 17).
RAND *TR603-2.1*

that trucks had financial advantages over railroads because of the way in which infrastructure construction and maintenance are financed.

Trucking companies using the federally funded highway system were able to offer more flexibility and reliability at competitive rates. The cost of building and maintaining highway infrastructure is charged indirectly to highway users through motor-vehicle fuel taxes. This gives trucking companies an advantage over railroads because they pay only for infrastructure capital and maintenance costs when they use the system, helping to insulate them financially from changes in freight transportation demand.[2] Railroads, on the other hand, bear the full cost of building and maintaining their infrastructure, and a large fraction of this cost is independent of traffic volume. Consequently, railroads are more highly exposed to financial risk from economic changes and are also more conservative about investing in additional capacity (AASHTO and Cambridge Systematics, 2006, pp. 3-9–3-11).

To more fully realize scale economies, spread risk, and better compete with other modes, railroads began to merge and shed underused assets during the 1960s and 1970s. Government regulation hindered the railroads' efforts to merge their operations, discount rates for large

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[2] A fairly large fraction of the maintenance costs that railroads face are fixed and independent of the volume of traffic moving over the rails. In contrast, truck owners pay for the maintenance of the highway system through fuel taxes, which are directly dependent on how much business they have. Trucking companies can set their rates equal to their marginal costs and survive. Simple economic theory shows that perfectly competitive railroads will always go bankrupt because average cost will always be higher than marginal cost, since the fixed costs are so high. A good discussion of this may be found in Keeler (1983).

customers, and abandon underperforming track. The Staggers Rail Act of 1980 (P.L. 96-448) eased regulatory oversight over railroads and facilitated a large number of mergers between major railroads so that, of the 41 Class I railroads that existed in 1978, only the seven companies described in Table 2.1 remain today.[3]

Capacity: Infrastructure

Rail infrastructure consists of track and structures, yards, locomotives, cars, and signals. Together, with the people who operate them, these components provide rail services. The focus on tracks as a single metric of rail capacity is therefore misleading. Further, statistics about railroad-track mileage can be confusing because there are other characteristics, such as the number of parallel tracks and the slope of the terrain, that influence operations and the amount of freight that can be carried over a particular track segment. All of this infrastructure must be maintained in good condition, or operating speed will consequently be reduced and safety will be compromised. To understand trends in infrastructure, it is necessary to understand all four of these issues.

Table 2.1
Class I Railroads (2006)

Region	Railroad	Miles Operated	Miles Owned	Revenue ($ millions)	Employees	Carloads (1,000s)	Tons (1,000s)
West	BNSF[a]	32,154	23,733	12,846	39,358	8,727	498,122
	Union Pacific	32,426	26,949	13,545	51,095	7,875	503,056
	KCS[b]	3,197	2,710	800	2,787	429	30,781
	Soo Line[c]	3,511	1,680	687	2,699	357	22,013
East	CSX	21,357	17,535	7,689	30,486	6,537	409,487
	NS	21,184	16,614	8,527	29,880	5,800	325,780
	Grand Trunk[d]	6,736	6,281	2,025	6,133	1,416	109,483
Class I freight total		120,565	95,502	46,118	162,438	31,142	1,898,721
U.S. rail freight total			140,249	47,878	181,807		
Class I share of total (%)			68	96	89		

SOURCE: AAR (2006, pp. 69–76).

NOTE: Some Class 1 freight totals do not precisely match the column totals due to rounding.

[a] BNSF = Burlington Northern Santa Fe Railway.

[b] KCS = Kansas City Southern.

[c] Soo Line is the U.S. arm of the Canadian Pacific Railway (CP).

[d] Grand Trunk is the U.S. arm of Canadian National (CN).

[3] The Association of American Railroads (AAR) classifies railroads by operating revenue. The largest, referred to as Class I, had operating revenues in 2005 greater than $319.3 million.

Track

Track is often the focus of policy debates about railroad capacity because it is a statistic that is easily measured. While the volume of traffic on most routes in the United States can be easily accommodated using a single track, a faster train cannot pass a slower train or a train traveling in the opposite direction unless there are sidings. A segment of track does have a physical capacity limit, so once daily volumes of rail traffic reach that limit, a parallel track becomes necessary if volumes are to continue to increase. Road mileage also reflects the number of direct connections among destinations. The statistics used in this report make an important distinction between the terms *road miles* and *track miles*: According to AAR (2006, p. 45),

> "miles of road owned [or road miles]" is the aggregate length of roadway, excluding yard tracks and sidings, and does not reflect the fact that a mile of road may include two, three, or more parallel tracks. "Miles of track owned" [or track miles] includes multiple main tracks, yard tracks and sidings.

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 railroads (Stover, 1997, p. 192). Since that time, according to data provided by AAR, the total miles of Class I railroad in the United States has fallen by 45 percent to 140,249.[4] Over this period, there have been revolutionary changes in the transportation system with the introduction of the interstate highway system and air travel. In addition, technological and operational advances have improved productivity and effectively increased capacity of all modes of travel, including rail.

Mileage statistics portray a relevant but incomplete picture of rail capacity since passage of the Staggers Rail Act (P.L. 96-448). Despite the decline in railroad miles, Figure 2.2 shows that the industry has been transporting a growing volume over a smaller network (in terms of track miles). These changes reflect both efficiency improvements and significant structural changes within the railroad industry.

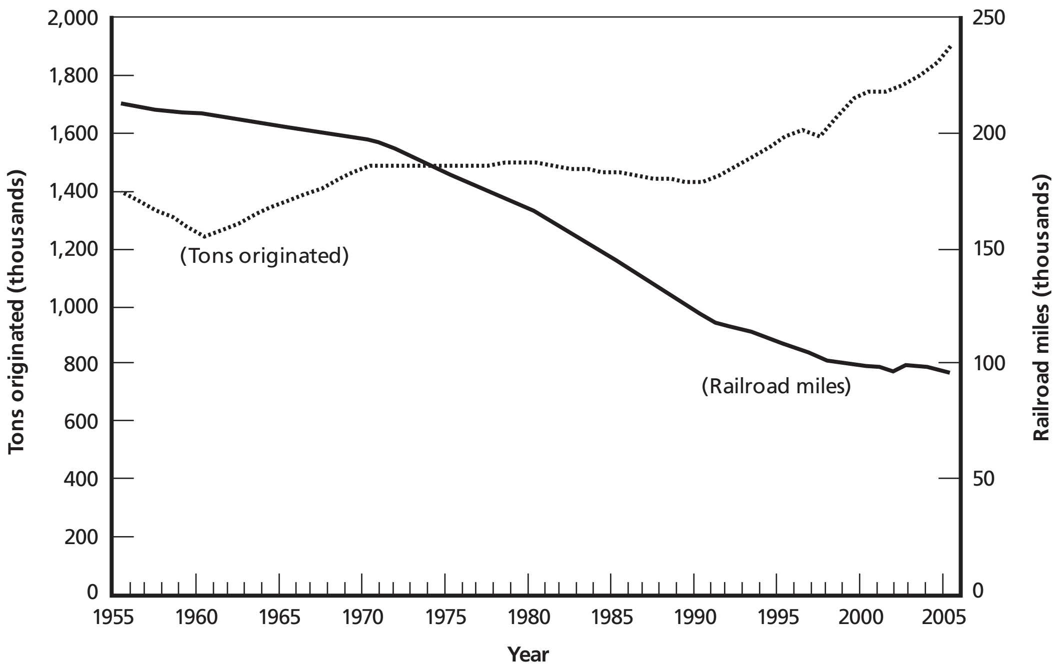
Commonly cited statistics overstate the decline in total railroad mileage because shortline and regional railroads acquired much of the road and track formerly owned by Class I railroads. Much of this track is still a vital part of the railroad network, but some of the old track cannot handle the weight of modern trains, and current volumes do not justify upgrading them (McClellan, 2007, p. 33).

The observed decline in road miles accurately reflects the abandonment of parallel routes and the abandonment or sale of routes with low volumes or high maintenance costs. Railroad service, for example, is no longer needed in communities in which heavy industry no longer exists, mines have stopped producing, and customers now prefer to use trucks to move their freight. Depending on where this road is located, this may or may not reflect a reduction in capacity. Maintaining a spur route to shuttered industrial facilities would add no real capacity, but an underused parallel route could provide needed capacity as demand grows, opportunities for economic development, or flexibility when service on the main line is disrupted.

With the assistance of the railroads and AAR, a 2007 Cambridge Systematics study identified the primary corridors over which most traffic travels (Cambridge Systematics and AAR, 2007, §4.1). These measured 52,340 miles in total length. This information underscores the

[4] AAR (2006, p. 3). Note that this figure is comprehensive: Total miles of track operated include Class I, regional, and terminal railroads.

Figure 2.2
Miles of Railroad and Tons Originated (1955–2005)



SOURCE: Calculated using data from AAR (2006, p.28).
NOTE: Some values from 1955 through 1990 were interpolated. It is reasonable to assume that the actual values in each intervening year would have been less smooth and that the actual peaks and troughs might have been more extreme than depicted here.
RAND *TR603-2.2*

difficulty of relying on publicly available aggregate railroad-mile data to analyze railroad capacity; even after 50 years of track abandonment, most traffic travels over a third of the network.

Track mileage statistics account for the total length of track, including the length of track in rail yards. One mile of triple-track road is counted as three miles of track. There are publicly available time-series statistics for the amount of road and railroad track owned by Class I railroads, but there are no aggregated and publicly available statistics with greater detail.[5] For instance, it would be relevant to this analysis to know the percentage of main-line track that is double-tracked or how rail-yard capacity has grown or decreased over time. Statistics for track miles are available only for Class I railroads and do not include short-line and regional railroads. It is impossible to know how much total track was sold to small railroads and how much was abandoned. Railroads were likely adding capacity to their main-line routes and yards while selling and abandoning track that they did not need elsewhere. It is also possible that the railroads were abandoning sidings and extra track along the major routes to eliminate capacity and reduce maintenance costs; it is necessary to distinguish among these types of deaccession to assess the impact of abandonments on railroad capacity.

Dividing the miles of road by the miles of track creates an aggregate metric showing how the ratio of track to road in the network has changed over time. As shown in Table 2.2, the length of road and track have both declined by approximately 40 percent since 1980, but

[5] The information appears to be available for sale by at least one private company.

Table 2.2
Railroad Miles (1955–2005)

Year	Track	Road	Ratio of Track to Road
1955	350,217	211,459	1.656
1960	340,779	207,334	1.644
1970	319,092	196,479	1.624
1980	270,623	164,822	1.642
1990	200,074	119,758	1.671
1996	176,978	105,779	1.673
1997	172,564	102,128	1.690
1998	171,098	100,570	1.701
1999	168,979	99,430	1.699
2000	168,535	99,250	1.698
2001	167,275	97,817	1.710
2002	170,048	100,125	1.698
2003	169,069	99,126	1.706
2004	167,312	97,662	1.713
2005	164,291	95,830	1.714
% change 1980–2005	–39.3	–41.9	4.4

SOURCE: AAR (2006, p. 45).

the ratio of miles of track to miles of road has grown by 4.4 percent. One likely explanation is that, while the extent of the system has shrunk, capacity on the remaining network has actually grown. Another likely, but conflicting, explanation is that this reflects the abandonment of low-capacity routes while not increasing the capacity of the yards and existing double-tracked main lines. Publicly available data are not at the resolution necessary to resolve this conflict.

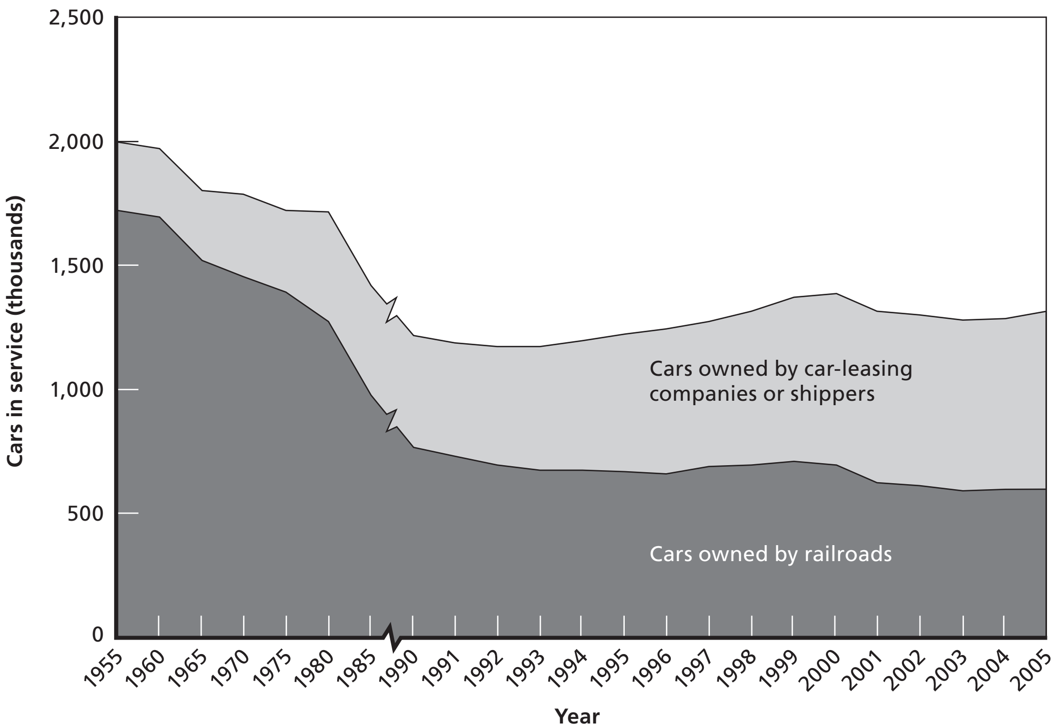
Cars and Locomotives

Shortages of either rail cars or locomotives reduce the capacity of the rail system. An excess of cars and locomotives is also costly because they tie up capital that could be directed elsewhere.

The number of freight rail cars in service declined between World War II and 1990 but has stabilized since then to between 1.2 million and 1.4 million.[6] Figure 2.3 shows the number of rail cars in service that are owned by railroads and shippers. Another important trend is the average capacity of the rail cars themselves, which has grown from 53.7 tons to 97.2 tons from 1955 to 2005 (AAR, 2006, p. 53). Today, most rail cars have a capacity of 70 to 100 tons,

[6] The statistics on rail cars, or rolling stock, cited in this report exclude passenger cars. Were passenger rolling stock included, the decline in the total number of rail cars would presumably have been steeper, because passenger rail travel has declined sharply over the time series and privately operated passenger service ended in the 1970s.

Figure 2.3
Freight Rail Cars in Service



SOURCE: Based on data from AAR (2006, p. 51).
RAND *TR603-2.3*

but newer aluminum coal gondolas can carry 122 tons (Armstrong, 1998, p. 90; Stover, 1997, p. 259). Over just the past 10 years, rail-car capacity has grown by more than 5 percent.

The average capacity reflects changes in the kinds of cars in service and how they need to be used. The mix of freight traveling by rail has changed over time and so have the needs for different kinds of rail cars. Table 2.3 shows that coal traffic has doubled since 1970 and mixed-freight traffic has exploded from 10 million tons in 1970 to 120 million tons in 2005 (AAR, 1982, p. 6). Most other types of freight have become less significant, reflecting the growing demand for energy and the growth in international trade.[7] Coal, mineral, and ore rail cars need to have a large capacity because these commodities are dense and transported in very large volumes. The capacity of intermodal flat cars is also increasing; new articulated flat cars each carry 10 double-stacked shipping containers in five wells.

The number of locomotives in service fell from 31,395 in 1955 to 18,000 in 1992 (AAR, 2006, p. 49). Between 1925 and 1960, the railroad industry underwent a technological transformation from steam power to diesel-electric. The appeal of diesel-electric locomotives was originally their relative fuel efficiency and low maintenance costs, among other advantages (Stover, 1997, p. 212). Later, as the technology matured, locomotives became increasingly powerful. Each one of these more powerful locomotives can haul more tons of freight, and this trend has continued to reduce the number of locomotives needed. The railroad industry has

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[7] According to AAR (2006, p. 26), miscellaneous mixed shipments make up almost all intermodal traffic and account for about two-thirds of intermodal tonnage.

Table 2.3
Tons of Rail Freight Originated, by Commodity

	1970		2005		% Change
Commodity	**Tons**	**% of Total**	**Tons**	**% of Total**	**1970–2005**
Coal	404.6	27.2	804.1	42.4	98.7
Chemicals[a]	91.6	6.2	167.2	8.8	82.5
Nonmetallic minerals	163.3	11.0	145.7	7.7	–10.8
Farm products	134.2	9.0	140.4	7.4	4.6
Miscellaneous mixed shipments[a]	10.6	0.7	119.8	6.3	1,030.2
Prepared foodstuffs[b]	110.1	7.4	102.2	5.4	–7.2
Metallic ores[b]	126.7	8.5	60.0	3.2	–52.6
Total	1,485.0		1,898.7		27.9

SOURCES: Data for 1970: AAR (1982, p. 6). Data for 2006: AAR (2006, p. 29).

[a] Not a top-five commodity in 1970.

[b] Not a top-five commodity in 2005.

also changed dramatically over the past 50 years in terms of the composition of traffic and distances traveled. Before 1975, many locomotives were used for passenger service. When the National Railroad Passenger Corporation (Amtrak®) was formed in 1971 to operate intercity passenger-rail travel formerly operated by private railroads, these locomotives fell out of the Class I railroad data (Stover, 1997, pp. 234–237). Reflecting the rise of the short-haul trucking industry and general structural changes in the economy, there are also fewer short-haul trips by rail than in the past. This has directly led to large increases in locomotive productivity, and locomotives are hauling freight longer distances, so the growth in ton-miles does not imply a growth in locomotives.

The number of locomotives in service grew by 27 percent between 1992 and 2005 as the volume of freight continued to grow. While locomotive productivity improvements slowed over that period, Table 2.4 shows that locomotives were 26 percent more efficient in 2005 than in 1992. Part of this can be explained by the fact that the average horsepower per locomotive unit in service has continued to increase as technological improvements continue to be made to the basic diesel-electric design. These improvements include computer-controlled fuel injection and improved electric motors (Armstrong, 1998, p. 70). Over 40 percent of the current locomotive fleet was built after 1995.[8]

Signals

Track signalization is an important determinant of rail network capacity. While many branch lines do not need signals because they do not have a high volume of traffic, most Class I rail uses some form of automatic block signaling (ABS) to ensure that the track is clear of other

8 Calculated from AAR data from 1996 to 2005 and includes rebuilt locomotives.

Table 2.4
Locomotive Productivity (1955–2005)

Year	Ton-Miles (millions)	Locomotives in Service	Productivity (track miles per engine)
1955	623,615	31,395	19,863,513
1960	572,309	29,031	19,713,720
1965	697,878	27,780	25,121,598
1970	764,809	27,077	28,245,707
1975	754,252	27,846	27,086,547
1980	918,958	28,094	32,710,116
1985	876,984	22,548	38,894,093
1990	1,033,969	18,835	54,896,151
1992	1,066,781	18,004	59,252,444
1995	1,305,688	18,812	69,407,187
2000	1,465,960	20,058	73,086,050
2005	1,696,425	22,779	74,473,199

SOURCE: AAR (2006, p. 49).

trains and to improve capacity.[9] ABS works by breaking up a rail line into a number of *blocks*. Only one train is allowed to be in a block at any time, and the system of signals lets the locomotive engineer know whether it is okay to proceed or not. The rails carry an electronic current that responds to whether a train is on the track and relays this information to a signal, next to the track and in the cab, for the locomotive engineer to see. Block lengths are determined by train length and stopping distance. Stopping distances vary by terrain and train weight. Since trains have been getting longer and heavier, longer blocks are necessary. Having greater block lengths reduces the capacity of the track, so, according to one industry observer, "it may not be possible to get enough trains over the line to produce appropriate revenue" (Armstrong, 1998, p. 131).

Better signaling and communication technology improve the utilization of existing track. Signals provide critically important information to the engineer about when to stop and when to proceed to the next track segment—to the next block. To increase capacity, signals have been refined to additionally relay the speed of travel.

There are more advanced forms of signaling technology that can further increase capacity. Centralized traffic-control (CTC) systems use a dispatcher located in a consolidated control center. Computer-aided dispatching systems have automated most dispatching functions, allowing for further productivity and capacity improvements. Armstrong (1998, p. 140) wrote,

> Single-track with CTC is considered to have about 70 percent of the traffic-handling capability of ABS double-track. . . . Pulling up some of the second track, but leaving long "passing track" sections connected with high-speed turnouts reduces track investment, main-

[9] Armstrong (1998, p. 126) noted, "it is perfectly possible to operate a railroad safely without signals. . . . [T]he purpose of signals is not so much to increase safety as it is to step up the *efficiency* and *capacity* of a line in handling traffic."

> tenance, and taxes while improving the flexibility of handling traffic [that] must move at much different speeds in the same direction. About 50,000 miles of line on U.S. railroads are so controlled.

The U.S. Federal Railroad Administration (FRA), which is responsible for enforcing rail safety, has made implementing a new generation of signaling technology called positive train control (PTC) a priority since 1997. In addition, "this issue has been on the National Transportation Safety Board's Most Wanted List since the list's inception in 1990" (Price and Southwick, 2006, p. 75). PTC systems are comprised of a multitude of advanced computing and communication equipment to improve the monitoring of trains on a railroad network. This will provide more accurate information to dispatchers and train operators, which, in addition to improving safety, is anticipated to increase the capacity of the existing track, increase the efficiency of rail operations, and reduce operating and maintenance costs. According to FHWA (2007),

> Pilot versions of PTC were successfully tested a decade ago, but the systems were never deployed on a wide scale. Other demonstration projects are currently in the planning and testing stages. Deployment of PTC on railroads is expected to begin in earnest later this decade.

The reasons given for the slow development and implementation of PTC systems include technological challenges and a lack of standards. Perhaps more importantly, developing and implementing PTC is extremely expensive, and safety benefits alone fail to support a federal regulatory mandate or voluntary action by the railroads (FRA, 2005).

Maintenance

Locomotives run more efficiently and are less likely to malfunction on well-maintained rail infrastructure. Trains must travel more slowly on track that is poorly maintained. Poorly maintained tracks and cars increase the risk of derailment (Armstrong, 1998, p. 95). Breakdowns, malfunctions, and derailments, in addition to being dangerous and costly, result in disruptions to service that seriously reduce the capacity of the entire network. McClellan (2007, p. 33) noted that "even planned downtime for maintenance . . . can play havoc with both schedule reliability and capacity," so it is reasonable to assume that *unplanned* downtime would be much worse.

When railroads are inspecting or maintaining a section of track, it cannot carry trains. Increasing the frequency of either reduces track capacity. As well, as track volumes increase, the ability to perform maintenance is limited, potentially leading to more-serious concerns. One important innovation that helped to improve railroad productivity was increasing the speed at which railroads can replace ties and track and perform other inspection and maintenance activities.

Railroad maintenance is very capital intensive because it involves adding new ballast and replacing worn track and damaged ties. It does not appear that railroad financial statements differentiate between expenditures on maintenance and on new construction. According to AAR (2006, p. 15), the railroad industry as a whole has historically devoted between 17 and 20 percent of total expenditures to "way and structures," which include maintenance and new construction of bridges, rail bed, and track. Adjusting financial data for inflation, expenditures on ways and structures have declined in real terms, as shown in Table 2.5. Since the length of track requiring maintenance has been declining, this was expected. It is also interesting to note that real expenditures per mile of track have increased over time. The industry has become much more capital intensive; it is using heavier rail, investing in more-advanced signaling technology, and must also design structures for heavier trains (Armstrong, 1998, p. 36).

During the difficult period for the railroad industry from the 1960s through the mid-1980s, some railroad networks suffered from inadequate maintenance.[10] Net railroad operating income is growing, and the average annual return on shareholder equity over the past 10 years has been 8.57 percent. This is far higher than the 2.57 percent in 1960 or the 0.43 percent in 1970 but remains below the historical cost of capital as determined by STB.[11] There are no published data on the physical condition of railroad track, structures, or cars, so it is not possible to determine, by reviewing public data, whether the condition of this infrastructure is improving over time. However, because maintenance is so capital intensive, the financial health of the industry is a reasonable indicator of spending on maintenance, and these

Table 2.5
Annual Expenditures on Maintenance and Infrastructure

Year	Way and Structure Expenditures (2006 $)	Miles of Track	Way and Structure Expenditures per Mile
1955	10,266,420	350,217	29.31
1960	7,983,518	340,779	23.43
1970	8,241,639	319,092	25.83
1980	11,888,593	270,623	43.93
1990	6,490,760	200,074	32.44
1996	5,631,262	176,978	31.82
1997	5,754,043	172,564	33.34
1998	5,736,691	171,098	33.53
1999	6,025,654	168,979	35.66
2000	5,796,969	168,535	34.40
2001	5,741,215	167,275	34.32
2002	6,065,400	170,048	35.67
2003	6,264,220	169,069	37.05
2004	6,707,378	167,312	40.09
2005	6,598,171	164,291	40.16

SOURCE: AAR (2006, pp. 15, 45) with CPI adjustment.

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10 A good example of this phenomenon was the poor condition of the track owned by Penn Central when it declared bankruptcy in 1970 (Stover, 1997, p. 237).

11 Calculated using data from AAR (2006, p. 21). The cost-of-capital issue has been complicated by the fact that STB has recently proposed using a new methodology, the capital-asset pricing model (CAPM), to compute the cost of capital. Using the new CAPM method would lower the cost of capital below this number. See STB (2007a) for details.

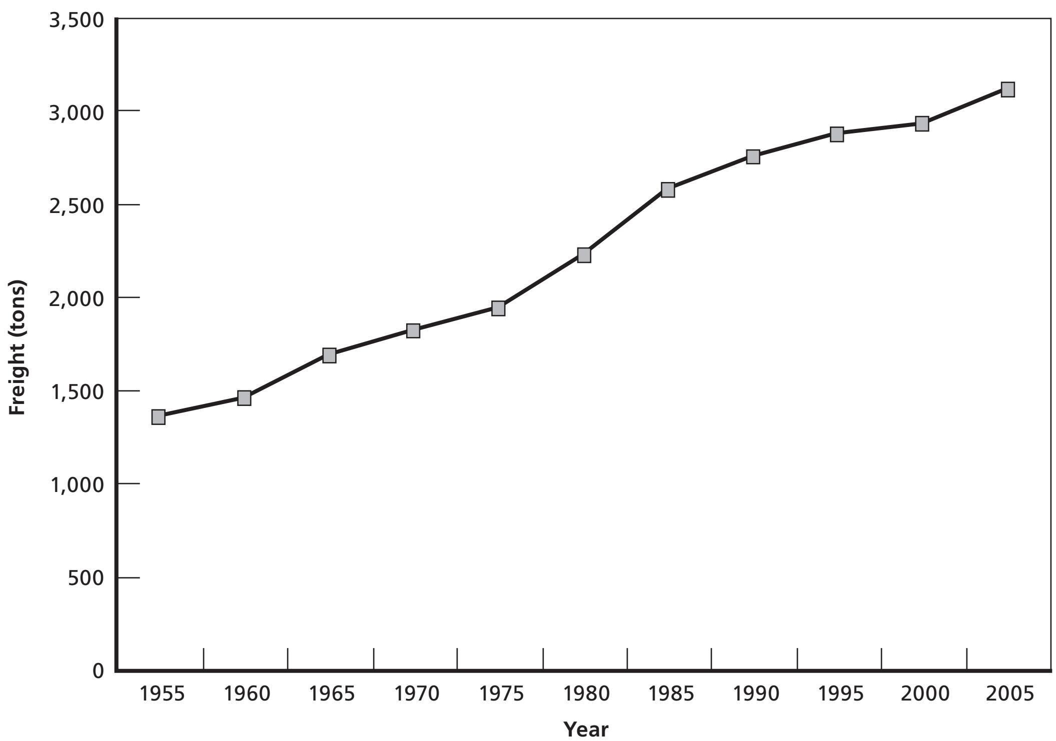
financial statistics provide the only public information about industry spending on railroad maintenance.

Capacity: Motive Power

Trains are pulled by powerful, fuel-efficient diesel-electric locomotives. The basic design of this technology was developed in the 1920s, when General Electric combined diesel technology with electric traction motors (Stover, 1997, p. 213). As newer locomotives replace old ones, average motive power should be steadily increasing; AAR (2006, p. 49) has claimed that average locomotive horsepower, nearly 3,500 hp in 2006, increased by 51 percent since 1980.

Railroad operators make trade-offs between train speed and weight. While horsepower has increased, trains are also hauling increasingly heavy loads, as shown in Figure 2.4. According to the rail industry, train speeds average between only 20 and 30 miles per hour (Railroad Performance Measures, undated). That is a gross average and includes periods during which trains are sitting on sidings. Speeds are highly variable depending on the carrier, the region and geography, and the weight-to-horsepower ratio of a train. Several recent Union Pacific news

Figure 2.4
Average Tons of Freight per Train Load (1955–2005)



SOURCE: Based on data from AAR (2006, p. 37).
RAND *TR603-2.4*

releases announced that the railroad was increasing speeds in parts of Nebraska from 49 mph to 55–60 mph and through parts of Texas from 10 mph to 49 mph.[12]

Capacity: Operating Strategies

The most flexible and least expensive way for railroads to change the capacity of a route is by adjusting operating strategy. Building additional track is expensive because it is costly to maintain and drains resources that might be better employed elsewhere (McClellan, 2007, p. 32). While adding (or ripping up) track is a long-term adjustment to capacity, reducing the speed of trains along a route or increasing the number of cars per train are flexible and temporary ways to increase capacity. Changes in operating strategy, though, often have quality-of-service implications.

There are at least five operating strategies that railroads use to manage capacity more responsively and at lower cost than adding track and locomotives. They can adjust rates, refuse traffic, adjust operating speeds, adjust train productivity, and attract unit trains.[13]

Adjust Rates

The railroad industry is highly concentrated in the hands of seven railroads. Competition is further limited by their geographical concentration, with rail transport in the East predominantly carried by CSX and NS and, in the West, by Union Pacific and BNSF. There are significant barriers to potential competitors entering the market, and this gives existing railroads pricing power.[14] The industry also has relatively high fixed costs and exhibits increasing economies of scale. To optimize the productivity of their track, locomotives, and crews, railroads will *eliminate* excess capacity, *improve* service performance, and *lower* their rates. Figure 2.5 shows rail rates, measured using the proxy revenue per ton-mile, and freight volume, using ton-miles, since 1980. Indeed, rates have fallen while volume has increased.

However, rates have risen in the last two years of data, suggesting that traffic density has increased to a level at which railroads may no longer want to stimulate demand by reducing rates. If this characterization is accurate, railroads are now in a position to raise rates and increase profits. In fact, according to Morgan Stanley, railroads are no longer offering generous volume discounts to large customers and are aggressively increasing rates (Greene, 2007, pp. 4–6). In addition to boosting industry profits, this could indicate that the railroad industry is actually facing capacity constraints and is seeking to reduce demand though higher rates.

Rate structures are also a tool that railroads can use to manage demand in relation to infrastructure capacity. Railroads can increase rates to reduce transportation demand at peak

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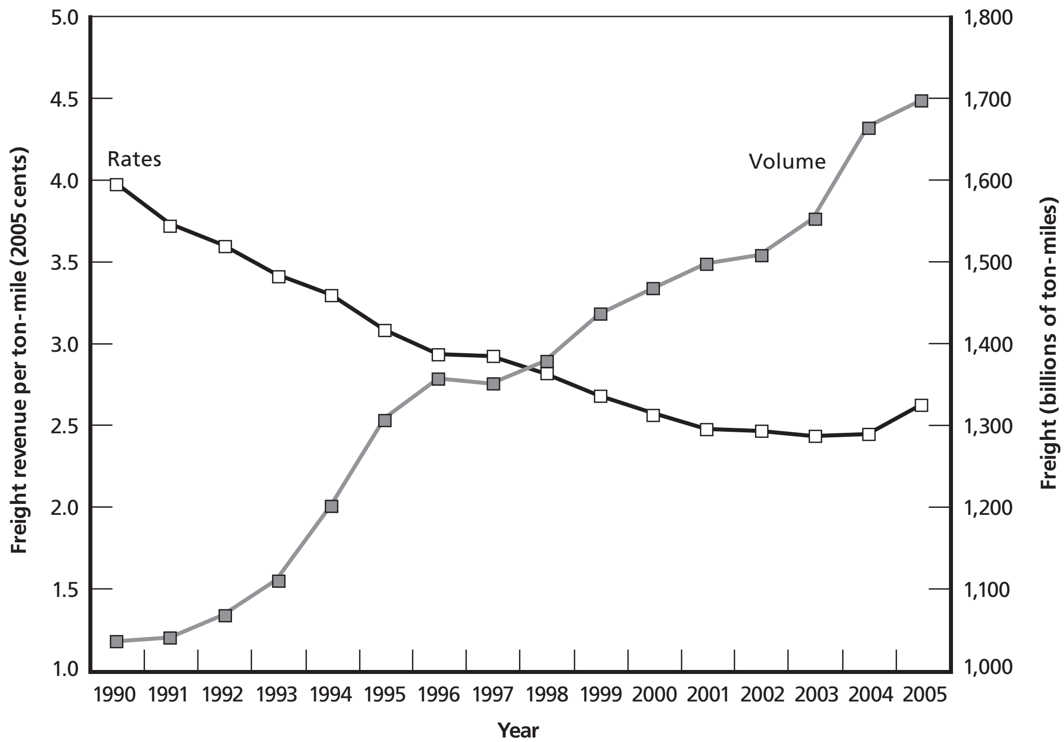
[12] Other railroads do not appear to publish similar speed data. Union Pacific (undated) routinely announces changes in operating speeds. See, for example, Union Pacific (2007).

[13] A *unit train* is a train consisting of cars all traveling to the same single destination. These trains are often leased by a single shipper.

[14] The railroad industry is clearly a natural monopoly, and railroads have pricing power. Pricing power allows railroads to increase rates above marginal cost. See Keeler (1983, Chapter Three) for a discussion of the complex economics at work in the railroad industry and the importance of traffic density to price.

Figure 2.5
Rail Rates (revenue per ton-mile) and Volume (ton-miles)



SOURCE: Calculated using data from AAR (2006, pp. 27, 30).
RAND *TR603-2.5*

times and for special handling services.[15] McCllellan (2007, p. 35) noted that this spreads demand so that the capacity of the network is used more efficiently. Because rail is more efficient over long distances, railroads can improve the capacity of their network if more freight is moving over longer distances. Railroads can use a rate structure, or negotiate preferential contracts with shippers, that favor longer hauls. Along with falling rates, the average length of haul doubled between 1955 and 2005 from 446.6 miles to 893.5 miles.[16] Railroads can also price discriminate between commodities and are attempting to specialize in their fastest-growing businesses—predominantly coal and intermodal unit trains. Table 2.6 shows how intermodal traffic has grown by nearly 400 percent since 1980, reflecting the rapid growth in trans-Pacific trade and the success that rail has recently had in competing with trucks in the logistics industry.

Shed Traffic

Railroads occasionally choose to limit the amount of traffic they will accept from some customers because that traffic generates low profits or the operating requirements reduce the capacity of the network and profitability is reduced. Because slow-moving trains must pull off to allow

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[15] Railroads exhibit pricing power because they are not perfectly competitive with each other or with trucks, but the level of competitiveness appears to vary by commodity and by region.

[16] This also reflects general economic trends; a large increase in the number of imports and consolidated manufacturing plants means that goods travel longer distances to market (AAR, 2006, p. 36).

Table 2.6
Annual Intermodal Movements

Year	Trailers	Containers	Trailers and Containers
1965	NA	NA	1,664,929
1970	NA	NA	2,363,200
1975	NA	NA	2,238,117
1980	NA	NA	3,059,402
1985	NA	NA	4,590,952
1990	3,451,953	2,754,829	6,206,782
1991	3,201,560	3,044,574	6,246,134
1992	3,264,597	3,363,244	6,627,841
1993	3,464,126	3,692,502	7,156,628
1994	3,752,502	4,375,726	8,128,228
1995	3,492,463	4,443,709	7,936,172
1996	3,302,128	4,841,130	8,143,258
1997	3,453,907	5,244,401	8,698,308
1998	3,353,032	5,419,631	8,772,663
1999	3,207,407	5,700,219	8,907,626
2000	2,888,630	6,288,260	9,176,890
2001	2,603,423	6,332,021	8,935,444
2002	2,531,338	6,781,022	9,312,360
2003	2,625,837	7,329,768	9,955,605
2004	2,928,123	8,065,539	10,993,662
2005	2,979,906	8,713,606	11,693,512

SOURCE: AAR (2006, p. 26).

faster trains to pass, capacity on a given route is reduced when there are high volumes of traffic moving at different speeds. Certain types of traffic, such as parcel delivery and passenger-rail service, including commuter trains and Amtrak, are very sensitive to delay and face penalties if schedules are not met. This is different from most freight trains, even intermodal container trains, which are not quite as time sensitive.

When the demand for commodity unit trains or mixed-freight trains increases, railroads may choose to shed the traffic that is highly schedule sensitive if their costs fall by more than the loss in revenue. The example of Union Pacific and CSX rapid train service presented in Chapter One illustrates how an unexpected surge in demand on the Union Pacific network led to lower profits, despite unprecedented levels of freight volume and its lucrative UPS contract, because operating expenses increased as a result of inefficient operations (Peltz, 2004). In response, Union Pacific had to eliminate the rapid rail service and, in effect, shed the UPS trains.

Intermodal traffic, consisting primarily of containers and trailers, is the fastest-growing segment of the railroad transportation market. Intermodal shippers require high speeds in order to make connecting schedules and reduce inventory costs. Many shippers do not currently require such high levels of reliability but, as the just-in-time practices used by manufacturing and retailing become more refined, this may change. If a large number of shippers begin to expect faster and more-reliable service from railroads, it seems possible that the conflicts between time-sensitive and non–time-sensitive freight could increase. Alternatively, shippers could change their business models and reduce inventories as they adjust their expectations of railroad reliability. Railroads may again attempt to offer scheduled freight service in the future only to find that their networks cannot handle the conflicting levels of service and, in response, decide to shed traffic instead of improving physical infrastructure.

Adjust Operating Speeds

The faster trains run, the more trains can be moved across a block of track in a day. For instance, if trains are being run at 20 miles per hour over a block 30 miles long, increasing the speed of each train to 40 miles per hour would result in a doubling of the capacity of that infrastructure. It would also mean that roads crossing tracks at grade would be subject to shorter delays when trains crossed the road. While increasing train speed would also increase operating cost, it would almost always be less expensive than building a parallel track.

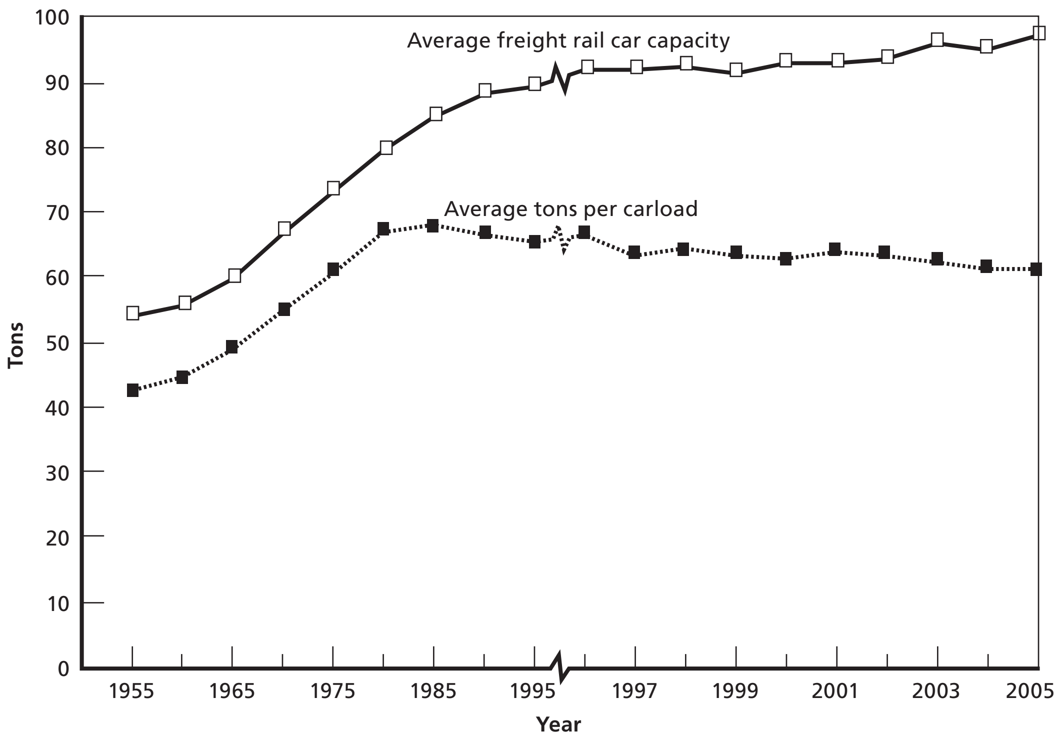
This is also a more flexible way to change the capacity of the track because if, for instance, it were in the railroad's interest to increase the capacity of a track segment, all it would have to do is increase the operating speed of the trains. Increasing speed is only possible if there is a sufficient number of locomotives available to provide the required horsepower.

Adjust Volume or Productivity

Other operating strategies employed by the railroads to add capacity include putting more freight on each rail car and increasing the number of cars in each train. While the average number of cars per train has remained fairly constant since the 1950s, the capacities of the cars themselves, as shown in Table 2.6, have grown from 53.7 tons to 97.2 tons between 1955 and 2005 (AAR, 2006, p. 53). The success of this strategy is limited by the types of freight being hauled. For instance, a standard 40-foot container can only hold so many tons of freight, but hopper cars have been steadily increasing in capacity. So this increase in car capacity partially reflects the importance of grain and, especially, coal. It also reflects technology improvements—for instance, an articulated five-well double-stack container car, which carries 10 containers, is considered a single rail car.

The average *capacity* of rail cars has increased since 1955 but, as shown in Figure 2.6, the average load in each car grew more slowly and has fallen since 1980. Between 1955 and 2005, the average carload has fallen from 79 percent of capacity to 63 percent of capacity. These data reflect divergent trends in commodity growth rather than declining productivity. As shown in Table 2.3, the volume of heavy commodities, such as coal and chemicals, is growing, as is relatively light intermodal freight. The productivity of rail cars is also influenced by how frequently they are used, so the velocity of rail cars is important. Velocity increases with train speed and decreases with the time spent waiting in a yard to be loaded or for a train to be built. Railroad cars for regular unit trains, like those for coal and intermodal trains, have high velocity, while cars that are used for specialty or seasonal commodities, such as chemicals and grain, have lower velocity.

Figure 2.6
Average Car Capacity and Actual Tons per Carload



SOURCE: Based on data from AAR (2006, pp. 37, 53).
RAND *TR603-2.6*

Heavier trainloads are more efficient, and they increase the capacity of the network by moving more tons more miles with the existing amount of track. Larger cars and more locomotives are needed, but the overall operating cost is lower. Table 2.7 shows that the number of cars per freight train has remained fairly constant despite increases in train productivity; there are practical reasons for this trend. The first is that rail yards and sidings have fixed lengths. They can be lengthened at some cost if land is available, but, otherwise, a train longer than a siding or yard will block the main line. Railroads, in coordination with shippers, are experimenting with longer trains, but these need to be loaded and unloaded rapidly and are not an option for most freight. A longer train also requires more time to build. Many freight trains are composed of cars moving freight for many shippers. In contrast with unit trains, this freight arrives in a stream over time, and the railroad typically keeps a train at a yard until it has reached a desired length. If the railroad's policy is to build longer trains, then more freight sits in the yard for longer periods of time. This reduces capacity by reducing the velocity of rolling stock and, in some cases, locomotives. It also reduces the quality of service by delaying some freight for many days and increases shippers' inventory costs.

Unit Trains

Railroads prefer to operate unit trains, in which every car is going from the same origin to the same destination, typically for a single shipper. With the passage of the Staggers Rail Act (P.L. 96-448), railroads were given the freedom to negotiate low rates and long-term contracts that increased the demand for unit trains (Armstrong, 1998, p. 221). There are no publicly

Table 2.7
Trends in Train and Freight Car Productivity

Year	Average Cars per Train (cars)	Average Tons per Train	Average Tons per Carload	Average Length of Haul (miles)	Productivity per Carload (ton-miles)
1955	65.5	1,359	42.4	447	19,035
1960	69.6	1,453	44.4	461	20,522
1965	69.6	1,685	48.9	503	24,621
1970	70.0	1,820	54.9	515	28,311
1975	68.6	1,938	60.8	541	32,894
1980	68.3	2,222	67.1	616	41,352
1985	71.8	2,574	67.7	665	44,971
1990	68.9	2,755	66.6	726	48,313
1995	66.3	2,870	65.3	843	55,032
2000	68.6	2,923	62.6	843	52,803
2005	68.9	3,115	61.0	894	54,473
% change 1955–2005	5.2	129.2	43.9	100.1	186.2

SOURCE: AAR (2006, pp. 35–39).

available statistics to report, but there seem to be growing numbers of coal, grain, and intermodal unit trains.

While many of these strategies are effective, they sometimes result in higher prices and lower-quality service. By shedding traffic or giving preferential rates to some customers while increasing rates charged to others, the railroads risk "antagonizing long-term base customers to the extent that they will seek other alternatives" (McClellan, 2007, p. 35). As demand rose ahead of physical increases in the capacity of railroad infrastructure during 2004 and 2005, the railroads employed many of these strategies to temporarily increase railroad capacity while they built new track, trained new crews, and waited for additional locomotives to be delivered. The result was, as predicted, poorer service and higher rates (White, 2006).

Capacity: Crews

Locomotives, rail yards, and intermodal terminals are operated by people. Without an adequate number of employees, the infrastructure does not function well and trains do not move. Labor productivity had been constrained by labor contracts dictating work rules that were not meaningfully changed until tense labor negotiations during 1991 and 1992. At that time, railroads negotiated greater flexibility in crew size and a 12-hour work day (Karr and Machalaba, 1991; Suro, 1992).

Providing adequate staffing and using crews efficiently are important determinants of capacity because work rules require that train crews can work only 12 hours before they must be relieved. The Union Pacific case study underlines the importance of crews: An insufficiently large workforce exacerbates rail capacity constraints. When the number of trains needing to use a route exceeds the capacity of the available track, trains might be delayed for many hours on sidings and in yards. The consequence of these all-too-frequent delays is that the crew must be relieved before the train reaches its intended destination, and a new crew must be bused to the delayed train before it can proceed. A railroad with an insufficient number of employees will not always have a crew ready, and the train will be further delayed (Peltz, 2004).

The Class I railroad workforce has fallen from 458,000 employees in 1980 to 162,000 in 2005. Overall, the decline in the number of workers does not appear to have had a direct impact on railroad capacity. Instead, it appears that, by substituting technology for labor and by negotiating more-favorable labor contracts, railroads have achieved strong increases in productivity in this period. In 1955, only 262 freight revenue ton-miles were moved per employee-hour. By 1980, that figure tripled to 863 ton-miles per employee-hour. In 2005, employee productivity had grown to 4,019 ton-miles per employee-hour (AAR, 2006, p. 41).

Capacity Summary

As the volumes of freight being transported by rail approach the capacity of the network, it seems reasonable to expect a reduction in the performance of the railroad network. Slower travel times and higher prices will likely have an adverse impact on the overall performance of the freight transportation system as loads shift from rail to highway. Improvements in operational efficiency seem to have allowed the current rail system to accommodate the surge in demand observed over the past 15 years. This raises concern about the ability of this streamlined system to accommodate further growth in rail traffic through operational-efficiency improvements and technology alone. If this concern is valid and if railroads underinvest in new road, rail market share will continue to fall and the number of trucks on the road will grow at an accelerating rate.

CHAPTER THREE

Performance

Rail capacity and performance are interdependent in many ways. Increasing speed improves performance and can increase capacity, but running trains at different speeds can reduce capacity and overall performance. Other strategies to increase capacity, such as shedding traffic or raising prices, reduce rail's value to some shippers. Reliability is important to all rail customers but may be measured differently; express parcel shippers measure delay in minutes or hours, while maritime intermodal shippers measure it in hours or days. Shippers of bulk commodities sometimes experience delays of weeks. While railroad capacity does affect speed and reliability, the mechanics differ from roads because a railroad network is centrally managed by planners and dispatchers. Despite this advantage, railroads can be overwhelmed by unexpected surges in demand. In addition, a railroad network operating near capacity may take more time to recover from a service disruption. A reasonable conclusion is that capacity constraints and operational problems will likely lead to rising prices and weakening performance. Such trends could lead to mode shifting or reduced demand for some commodities.

This chapter evaluates available data for each of these four general metrics of performance: average speed, reliability, prices, and resilience. It also reviews metrics of productivity and analyzes which matter, how they matter, which do not, and why.

Average Speed

Speed is an important metric of performance and a major determinant of transportation cost. Freight in transit is inventory not available for use in production or for sale. Capital tied up in inventory is not available to be put toward other productive activity. Because inventory costs are increasing, travel time matters more to shippers of high-value goods than to shippers of low-value goods.[1] While the travel speed of a train is an important determinant of travel time, average speeds are a more important metric in determining the velocity of the system, because trains make frequent stops. The frequency and duration of stops are determined by how well the network is being run and how close it is to operating at maximum capacity. A slow train with few stops will likely have a greater average speed than a fast-running train that is frequently delayed on a siding while other trains pass. The velocity of a railroad's network is a metric that captures how fast its trains are moving in aggregate. While it may miss important facts, such as super-fast trains carrying high-value goods, it does appear to be a good measure

[1] We use inventory models developed in Leachman (2005).

of how well a railroad is serving all of its customers. Falling average speeds imply problems, and rising average speeds imply improvements.

Six Class I railroads report weekly average speed for all trains in the system for several different types of trains, including grain, coal, and intermodal.[2] For all railroad operators, intermodal trains have higher velocity than the railroad average, while coal unit trains are slower. Average speeds for each of the railroads are presented in Table 3.1 by train type.

Speed should be correlated with the value of the cargo because shippers are usually willing to pay more for priority service to reduce inventory costs, and inventory costs are directly related to the value of the commodity. According to *2002 Commodity Flow Survey*, coal has an average value of $18 per ton, grain has an average value of $92.44 per ton, and intermodal freight has an average value of at least $1,627 per ton.[3]

Further analysis of *Commodity Flow Survey* data clearly shows that low volumes of high-value freight travel by rail. A notable exception is motor vehicles and parts, which have an average value of nearly $6,000 per ton.[4] Data from *Commodity Flow Survey* and AAR are combined in Table 3.2 to show the top commodities carried by rail by volume, weight, and value. As expected, low volumes of high-value freight are transported on the railroads. The exception, far exceeding motor vehicles and parts according to the AAR, is intermodal freight. The high volumes of low-value freight reinforce the assumption raised earlier that, when given the choice, shippers will prefer lower rates and lower speeds to higher rates for faster speeds. An analysis of weekly speed data since April 2006 did not reveal any recent industrywide trend in average train speed. These data are plotted in Figure 3.1.

Reliability

As with speed, reliability matters more for high-value commodities than for low-value commodities. The reason is also related to inventories; in this case, the concern is for safety stocks. Safety stocks are inventory that manufacturers and retailers maintain in case of unexpected demand or supply-chain disruptions. As economic production and retailing have continued to employ just-in-time operations, these inventories have been able to shrink. If rail transportation were to become less reliable, these gains would be lost, as rail customers would need to increase safety stocks. In the event that a manufacturer stocks out of materials, it still incurs costs for labor, rent, interest, and any other fixed costs. Retailer distribution centers also try to avoid stocking out of inventory, since doing so would lead to lost sale opportunities and might foment ill will from their customers.

Even under normal circumstances, it appears that railroads are not able to manage reliability well. While the timing and speed of trains are centrally controlled, the fact that most

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[2] See Railroad Performance Measures (undated). Note that statistics should not be compared between railroads, because average speeds are affected by characteristics unique to each network, such as grade and operating strategy.

[3] In *Commodity Flow Survey* (BTS and U.S. Census Bureau, 2005), parcel or courier, truck and rail, truck and water, and rail and water are all aggregated separately. Large portions of this intermodal freight travels partly by rail, including parcel freight. Parcel freight also travels by air. The average value of parcel freight is $38,715, while the average value of rail and water is $31.67. Most intermodal freight arrives at rail terminals via truck, so we assume that truck and rail freight is the best approximation, with a value of $1,627. We assume that maritime container freight is less than this, and UPS freight is greater.

[4] Calculated from BTS and U.S. Census Bureau (2005, Table 7).

Table 3.1
Average Train Speed (first quarter 2007)

Company	Train Type	Miles per Hour
BNSF	Intermodal	34.1
	Grain unit	18.6
	Coal unit	23.6
	All	23.4
Soo Line	Intermodal	28.0
	Grain unit	20.0
	Coal unit	20.5
	All	23.2
CSX	Intermodal	28.6
	Grain unit	16.2
	Coal unit	19.0
	All	20.2
KCS	Intermodal	29.0
	Grain unit	21.5
	Coal unit	21.9
	All	24.0
NS	Intermodal	26.9
	Grain unit	15.4
	Coal unit	18.2
	All	21.1
Union Pacific	Intermodal	25.6
	Grain unit	20.6
	Coal unit	19.9
	All	21.7

SOURCE: Average of speed data from January 5, 2007, to March 30, 2007, according to Railroad Performance Measures (undated).

freight trains do not run on a fixed schedule means that many shippers do not know when their freight will leave the terminal and arrive at its destination. Shippers have complained to STB about a general lack of reliability and that their freight sometimes gets lost.

There appears to be no consistent quantitative metric of how often trains are running late and by how many hours or days. Such data, similar to data collected for air travel, would be useful in analyzing the effects of changes in volume and disruptions on reliability throughout the entire network. It might be difficult to track reliability in this way, since railroads do not

Table 3.2
Major Rail Commodities, by Volume and Value (2002)

	Volume			Value	
Commodity (STCC, SCTG)[a]	**Ton-Miles (millions)**	**Tonnage (millions)**	**Carloads (1,000s)**	**Average ($/ton)**	**Revenue ($ millions)**
Coal (11, 15)	590,376	785.0	7,088	18.23	7,797
Cereal grains (01, 02)	141,825	137.7	1,471	92.44	2,711
Chemicals (28, 20)	57,167	157.0	1,866	359.61	4,658
Prepared foodstuffs (20, 07)	40,611	102.2	1,472	328.73	2,657
Motor vehicles and parts (37, 36)	12,095	37.8	1,831	5,911.07	3,731
Mixed freight (46, 43)	NA	97.2	6,650	3,756.69	4,900
Truck and rail[b]	45,525	NA	NA	1,626.86	NA
All commodities	1,261,612[c]	1,766.7	27,901	194.40	36,742

SOURCES: Tonnage, carloads, and revenue: AAR (2005). Ton-miles and value: BTS and U.S. Census Bureau (2005, Table 7).

[a] AAR reports commodity data using an old classification-code format, the Standard Transportation Commodity Code (STCC). A new format, used in *Commodity Flow Survey 2002* (BTS and U.S. Census Bureau, 2003), is the Standard Classification of Transported Goods (SCTG). These two formats cannot be directly compared, so this table should be interpreted with care.

[b] AAR publishes intermodal statistics differently from how it reports commodity statistics. A lot of intermodal freight is mixed, but not all mixed freight is intermodal.

[c] Ton-mile figure does not include intermodal freight. The average value for all commodities is a weighted average.

currently require reservations or, with the exception of intermodal service, run freight trains on schedules.

Excess network capacity allows railroads greater flexibility to run fast trains on the same routes as slow trains. As traffic density increases, railroads' ability to run trains at different speeds on the same line is reduced. This may reduce capacity so much that the additional revenue generated by the faster trains is less than what it would be if they simply ran additional slow trains. The result is that the railroads may decide to refuse time-sensitive freight in favor of freight with lower reliability demands.

Terminal capacity also plays a role in performance reliability. If a train cannot be moved into the terminal, it might have to sit on a main-line track until another train leaves. If there is a delay in loading and unloading freight cars or in assembling trains, operations might be disrupted elsewhere in the network.

Class I railroads post statistics on average terminal dwell time, measured by how many hours a rail car waits in a terminal after its train arrives or until its train departs. It is interesting to look at the standard deviations in the terminal dwell data for different terminals over time as a measure of reliability. Standard deviation measures the spread of a distribution of values around the mean. If variance in terminal dwell time is, in fact, related to reliability, then a railroad whose terminals have small standard deviations would seem to be more reliable than a railroad with large standard deviations in terminal dwell.[5]

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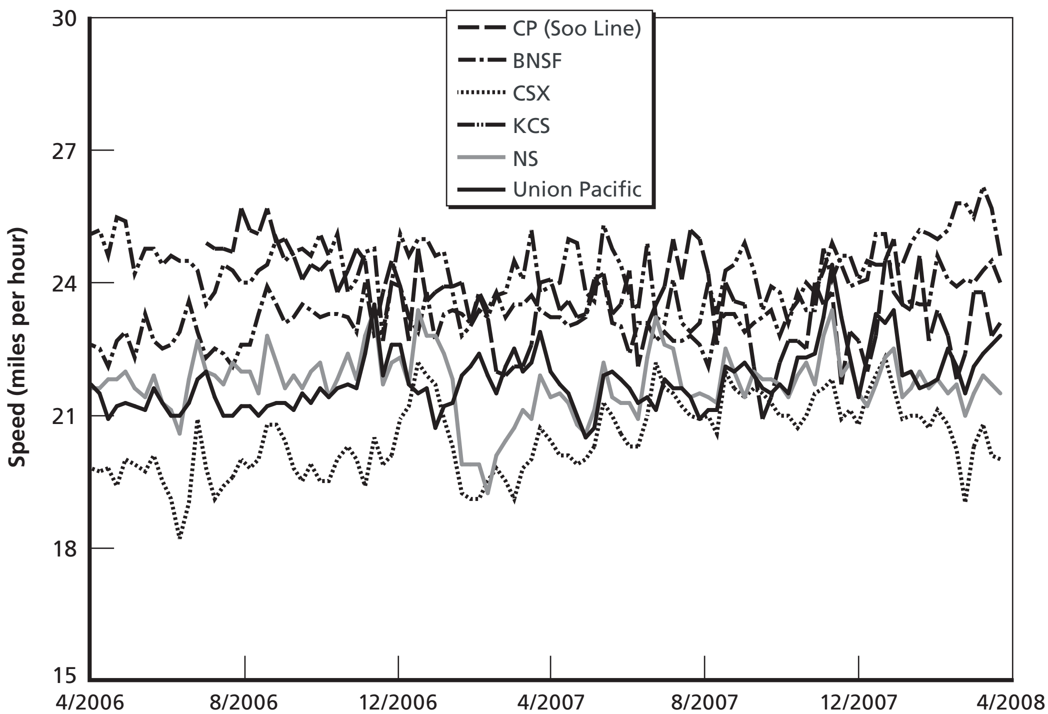
5 Without data that directly measure reliability, such as percentage of trains on schedule, we cannot test this assumption.

Figure 3.1
Average Speed



SOURCE: Railroad Performance Measures (undated).
RAND *TR603-3.1*

Weekly terminal dwell-time data are available for each Class I railroad's major terminals.[6] Over this period, BNSF's Memphis terminal had the shortest average terminal dwell time at 11.5 hours, and, during one week in July 2007, rail cars spent an average of only 8.8 hours in the terminal. CP's Toronto terminal has both the longest average terminal dwell time and the highest standard deviation; the mean dwell time over the entire period was 41.2 hours, with cars spending an average of 62.6 hours in the terminal during March 2006. Table 3.3 summarizes the descriptive statistics for each of the six reporting railroads, identifying the terminals with the highest and lowest reliability as measured by standard deviation, and the average standard deviation in terminal dwell for each railroad.

When the terminal dwell data are plotted, as in Figure 3.2, a clear and sustained increase appears in terminal dwell time beginning in December and lasting through January. This occurs too late in the year to be attributed to the seasonal surge in volume for retail merchandise for holiday sales, but it may be related to labor shortages as railroad employees take vacation.

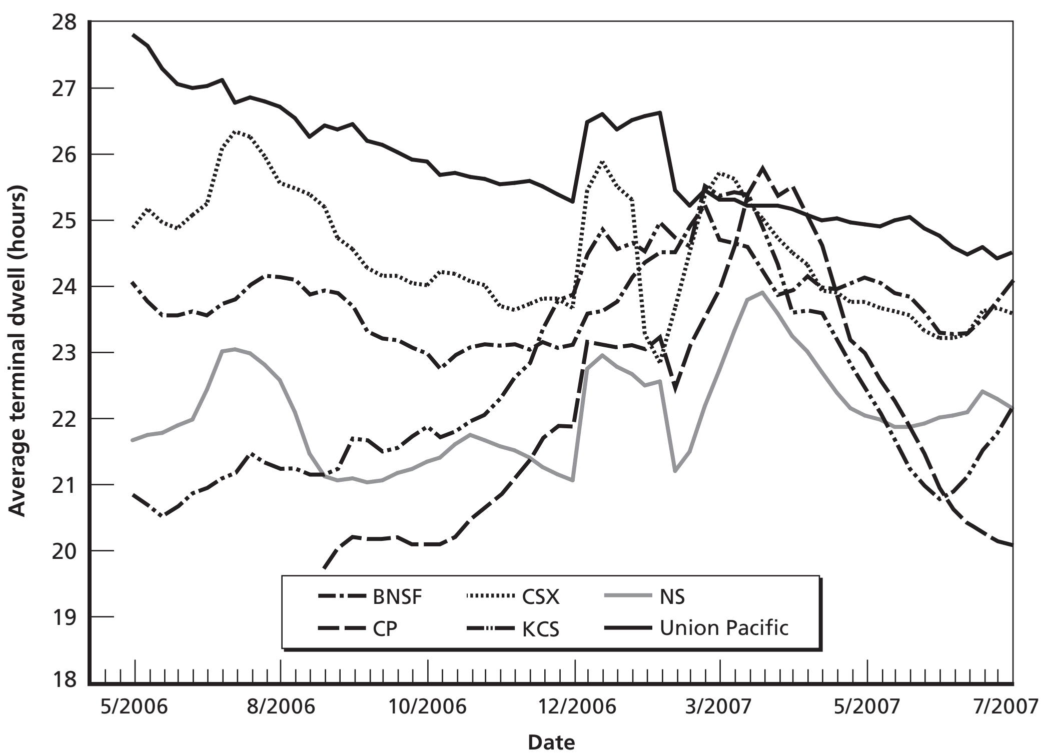
6 Data are kept at Railroad Performance Measures (undated) for 53 weeks, but we first copied data in April 2007, so our analysis covers April 2006 through August 2007.

Table 3.3
Terminal Dwell

Railroad	Average Dwell (hrs)	Terminals	Average St. Dev.	Most Reliable Terminal			Least Reliable Terminal		
				Name	Mean (hrs)	St. Dev.	Name	Mean (hrs)	St. Dev.
BNSF	23.8	11	3.4	Memphis, Tenn.	11.5	1.7	Denver, Colo.	27.4	6.5
Soo	21.6	10	3.9	St. Paul, Minn.	17.7	2.3	Toronto, Ontario, Canada	41.2	8.9
CSX	24.3	15	3.3	Chicago, Ill.	17.9	2.2	Selkirk, Manitoba, Canada	30.8	4.5
KCS	22.5	4	4.7	Laredo, Tex.	20.6	2.9	Shreveport, La.	30.3	6.3
NS	22.0	14	3.3	Linwood, N.J.	22.5	1.8	Bellevue, Wash.	28.2	5.6
Union Pacific	25.8	13	4.0	North Little Rock, Ark.	27.1	1.8	Houston/ Englewood, Tex.	34.3	6.6

SOURCE: Railroad Performance Measures (undated).

Figure 3.2
Terminal Dwell Time (moving average, May 2006–July 2007)



SOURCE: Railroad Performance Measures (undated).
RAND *TR603-3.2*

Prices

The cost of transporting freight is an important aspect of railroad performance. Ultimately, shippers make transportation decisions based on cost. While speed and reliability are important aspects of this decision, especially in how they determine inventory costs, price is the primary component of total transportation cost for most commodities.

Before the Staggers Rail Act (P.L. 96-448) was passed in 1980, rail prices were more tightly regulated. Railroad regulation had come into existence at the end of the 19th century in response to predatory price discrimination (Stover, 1997, p. 97). The Interstate Commerce Commission oversaw railroad rate changes, and, according to economist Theodore E. Keeler (1983, p. 24), they used "value-of-service" pricing to guide their decisions. The effect of this policy was that "the rate per ton charged for a high-value commodity is higher than the rate for a low-value commodity, even if transportation costs are the same."[7] While this led to distorted prices, it also prevented potentially devastating rate wars in competitive rail transportation markets (Winston, 2005, p. 2).

Following the Staggers Rail Act (P.L. 96-448), average prices fell over the subsequent 20 years. Winston (2005, p. 8) wrote that policymakers and shippers were concerned that prices would rise but that "deregulation has turned out to be a great boon for shippers." A December 2000 study on rail pricing by STB staff reinforces that finding, reporting that shippers saved nearly $32 billion in 1999 alone because prices were no longer fixed at their inflation-adjusted 1984 levels (STB, 2000, pp. 2–3). STB noted that the price reductions had benefited mostly consumers because competitive markets forced shippers to pass their savings on by keeping prices low.

An analysis of freight revenue per ton-mile, a useful proxy for rates because it represents both distance and weight, shows that real prices fell consistently between 1980 and 2003. These data, presented in Figure 2.5 in Chapter Two, is more recent than the data used in the analyses conducted by the staff at STB and by Winston. This reduction in rates was accompanied by increased volumes and increased productivity. Railroad expert Carl D. Martland (1999, 2006) documented that Class I railroads improved their profitability during this time. He concluded, however, that this would not have been possible without large increases in industry productivity. Martland (2006, p. 104) has also noted that rail rates began to rise in 2004.

Other studies, using more recent data, strongly support the hypothesis that railroad prices are increasing rapidly. The *18th Annual State of Logistics Report* indicated that railroad revenues increased by 13 percent in 2006 and that "since 2004 the rail industry has improved its freight revenue by 28.6 percent" (Wilson, 2007, pp. 8–9). Financial analyst William J. Greene of Morgan Stanley (2007, p. 1) viewed the railroad industry as attractive to investors in large part because it is raising its prices. Greene predicted that average prices will increase 3.5 to 6 percent annually through 2009.

Many railroad transportation contracts are proprietary and often specify additional logistics services beyond transporting a carload of freight from one place to another (i.e., warehousing, financial services, service-level guarantees). For this reason, despite published pricing tables, it is not possible to know how much most shippers are actually paying per ton-mile for rail transportation. There are probably different prices for different commodities, regions, and

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[7] Note that this is not a definition of *value-of-service pricing*; it is a primary effect of that policy.

times of the year.[8] It does appear that, on average, prices have begun to increase, and it seems reasonable to conclude that this is related to the increase in demand.

Productivity

By any measure, North American railroads have become extremely efficient and productive, moving growing volumes of freight over a shrinking infrastructure. As discussed in Chapter One, railroads are currently being utilized at a much higher rate than in the past.

A common metric of rail productivity is ton-miles per train-hour. This statistic "reflects both the number of tons hauled and the miles traveled during an average hour of freight train operation" (AAR, 2006, p. 38). Between 1980 and 1990, ton-miles per train-hour increased sharply but have since stayed steady at about 60,000 ton-miles per train-hour. It is possible to look at eastern railroads separately from western railroads, and this metric of productivity is lower in the East than in the West because freight travels, on average, shorter distances east of the Mississippi than west of it. While ton-miles per train-hour have remained relatively constant in the East since 1990, this metric has declined in the West from 71,619 ton-miles per train-hour in 1990 to 63,624 in 2005. This suggests decreasing average rail productivity in the western United States. A plausible explanation is that there are more movements of rail freight between markets within the West relative to the long-haul movements between the coast and the important rail terminals around Chicago and Kansas City. There are also an increasing number of coal movements in the western United States that, while not short, are not as long as the transcontinental routes.

Railroads have also continued to improve their energy efficiency. Since 1980, ton-miles of freight moved per gallon of fuel consumed have increased by about 50 percent. More-advanced locomotive technology plays a large role in this progress (Armstrong, 1998, pp. 78–79). This energy efficiency is giving railroads an important competitive advantage as diesel prices continue to rise. It also provides an additional incentive for shippers to move more freight by rail when possible. Future capacity constraints may restrict the ability of the rail network to accommodate this increasing demand and simultaneously provide a satisfactory level of service.

There is a large body of literature that evaluates rail productivity in detail and with more precision than in this descriptive overview.[9] According to one recent study, rail productivity growth increased significantly after the passage of the Staggers Rail Act (P.L. 96-448) and "has continued at the same pace as it had in the mid-1980's" (Bitzan and Keeler, 2003, p. 249). This growth is the result of technological innovations that allowed trains to run with crews of two instead of four or five, followed by changes in work rules and labor laws that operationally implemented these improvements. It is too early to predict the future rate of productivity growth in the railroad industry, but one recent study noted that rail productivity metrics indicate that the rate of increase began to decline in 2004 (Martland, 2006, p. 93).

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8 The railroads do have public rate tables available on their Internet sites, but many shippers negotiate separate rates. These public rates could likely be used in a more detailed analysis, but the structure is complex and would require effort outside the scope of this report.

9 A comprehensive survey of these studies is Oum, Waters, and Yu (1999).

Resilience

Railroads perform an important role in the global supply chain by transporting imports between seaports and inland markets. Railroads also haul large quantities of coal used to generate electricity for millions of Americans. Manufacturers rely on railroads to bring a steady stream of components to their factories and to deliver finished products to North American markets. When rail service is disrupted, valuable freight stands still with severe economic consequences. Trucks can usually change routes relatively easily when a highway link is severed. They may take more time to reach their destination, but they do not stop moving. Railroads travel along a fixed guideway and so cannot simply take arterial roads around a derailment or a mudslide.

Disruptions are inevitable, and, across all of the United States, they are frequent. Specific examples of major disruptions to the railroad network include the 2003 lockout at the San Pedro Bay ports, Hurricane Katrina in 2005, and the 2007 American River railroad trestle fire near Sacramento, California. More-common disruptions include derailments, mudslides, accidents at grade crossings, forest fires, and inclement weather. Disruptions affect rail service in two phases. At first, rail traffic is stopped until the blockage is cleared or the track is repaired. During this time, trains back up along a corridor, and some are rerouted along longer routes. This disrupts operations throughout the network as traffic volume unexpectedly increases along some routes and drops along others. At rail yards, shipments continue to arrive but do not leave. Once the main disruption is repaired, there is a surge in rail traffic as delayed trains all begin to move at once. This surge in traffic may continue to disrupt operations for some time.

While a disruption is extremely unlikely at any specific place or time, some sort of disruption is very likely to happen somewhere in North America within, say, the next month. While the length of most of these disruptions is usually short—a week at most—a disruption affects the entire network because there is little redundancy. If there were more parallel lines, for instance, then, if a landslide knocked out one route, trains could be more easily routed around it. But in the current system, parallel routes either have been abandoned or are already operating near capacity. While redundancy can create resilience, it is a capital-intensive solution. More important is how quickly railroad operations return to normal after the disruption (Sheffi, 2005). Resilience may have more to do with the flexibility of railroad operations or with good planning than with having redundant track, rolling stock, and locomotives.

This suggests two measures of resilience. The first is the extent to which rail operations are affected along routes not directly affected by the initial event. The second is how long it takes for all operations to return to normal. To our knowledge, neither of these metrics is being collected in an organized and consistent way. It is feasible, if likely challenging, to collect data that could be used to measure rail-network resilience in a meaningful way. Speed and reliability, measured at a high resolution in time and location, could be used to first model normal levels so that potentially unusual low speeds or high delays could be tested for statistical significance. This model could then be employed to see how a track closure disrupts the network and how long its effects last.

Currently available data are insufficient because they are available only for each railroad and in weekly increments. It seems likely that railroads have begun to collect data of sufficient resolution, but it seems unlikely that they are willing to share it with each other. Even if they were to share it with one another, the railroads may collect the data using incompatible methodologies. Another possibility is that third-party logistics providers, such as Yellow Transportation and Federal Express®, might have data sensitive enough to detect deviations from normal reliability.

There are clear private and public interests for measuring and improving the resilience of the railroad network (Willis and Ortiz, 2004, p. 26). Resilience needs to be measured so that efforts to improve it can be evaluated.

CHAPTER FOUR

Observations and Recommendations

An analysis of aggregate data shows that the productivity of the railroad industry has improved since the Staggers Rail Act (P.L. 96-448) was passed. Since 1980, the railroad industry is many times more productive and appears to be financially healthy. The broad implication of this is that the industry has improved capability to generate capital that can be used to maintain and improve its network. The industry has also become more cost and service competitive with trucks for long-distance freight transportation than it has been in the past.

However, aggregate data are incapable of telling the whole story because there are good reasons to believe that capacity and service quality vary by season, commodity, and region. For instance, in the weekly statistics for average speed, intermodal trains have higher average speed than grain unit trains. While that is informative, there is no publicly available information on weekly volumes of commodity flows over time, so it is impossible to evaluate whether cyclical and seasonal changes in volume affect velocity or any other measure of performance.[1] The movements of many commodities, such as coal and automobile parts, are regionally specific. While *Commodity Flow Survey* shows the volumes of different commodities moving between markets during a year every five years or so, this is only a snapshot. *Commodity Flow Survey* is incapable of measuring annual changes in volumes, let alone seasonal changes or more acute, unexpected surges in commodity flow.

Delay, lack of reliability, and slow travel times lead to mode shifting because firms choose the mode of freight transportation that allows them to fulfill their customers' orders in a timely manner and maintain their supply chains at the highest level of service and lowest cost. Despite the direct cost advantage of long-haul rail over long-haul truck, it is clear from the prevalence of national trucking firms that many companies find trucking to be more competitive or reliable. When a railroad is capable of offering improved performance, it is plausible that some shippers would choose to shift their freight from truck to rail, even freight as time sensitive as guaranteed-delivery parcel shipments. Railroads appear to be increasingly uninterested in serving low-volume shippers with inconsistent demand. The UPS example shows, however, that railroads will make an effort to improve service if there is sufficient volume to build a unit train between terminals.

An important point of this report is that there are public consequences to private actions. The example of decisions by UPS and Union Pacific illustrates how shippers make transportation decisions based on private cost, but their decisions affect other users of the transportation system and communities in which this infrastructure exists. In addition to the prices charged

[1] Note that weekly commodity volume data are available from AAR. However, the geographic aggregation of these data limits their utility.

by a trucking or railroad company to transport the shipper's freight, the shipper must consider the amount of time it will take for its goods to arrive at the correct destinations; the risk that its freight might get damaged, lost, or delayed; and other costs, such as paperwork, warehousing, and drayage. Railroads take actions that affect the overall cost of shipping freight, and shippers respond to these signals. Additionally, the cost of shipping freight does not include all of the external costs to other users (e.g., congestion, pollution, traffic accidents). In these areas, rail has certain advantages over trucking that benefit the public. If transportation were to be priced accordingly, using tolls, taxes, or subsidies, shippers would be more likely to make modal choices that benefit them and the public interest simultaneously.[2] The advantages of trucks over rail, especially for short- and medium-haul freight, would not likely change, but there could be social advantages.

Cost estimates for expanding the capacity of rail infrastructure to accommodate the expected growth in freight traffic volume range from $148 billion to $175 billion over the next 30 or so years (Cambridge Systematics and AAR, 2007, p. 7-1; AASHTO and Cambridge Systematics, 2003, p. 4). These estimates require many assumptions and focus on building more track and terminals but have been unable to calculate how additional operational and technological innovation might reduce or increase these costs. Such innovations drove the productivity growth and operational efficiency improvements that the rail industry has enjoyed over the past three decades while, for the most part, reducing infrastructure capacity. It is reasonable to expect PTC to be implemented throughout the industry within the next 30 years, but it is not yet known what the full, but likely considerable, cost will be. The benefits of PTC to rail capacity and performance are still not fully understood. On the other hand, large-scale rail projects have a history, around the globe, of cost overruns. A case study of 58 rail megaprojects showed that only about 15 percent were completed under budget and that cost "overruns above 80 percent are not uncommon" (Flyvbjerg, Bruzelius, and Rothengatter, 2003, p. 17).

These observations support three issues for further study to improve transportation policy and support transportation planning. The first issue is the need for improved reporting and public dissemination of railroad system and quality statistics. A vast amount of data is available for highways, but little comparable data are available for railroads, which are no less critical to the efficient flow of goods across the nation. Analysis of freight transportation in general and railroad transportation in particular is hindered by a lack of publicly available, detailed, and accurate data. This, in turn, impedes causal policy analysis and good public policy. There do exist ongoing efforts at all levels of government to improve the collection and dissemination of freight transportation data. Several local planning organizations and state departments of transportation have initiatives to improve the understanding of regional commodity flows. However, the limited resolution of *Commodity Flow Survey* and STB's *Carload Waybill Sample* (see STB, undated, and FRA, 2008) hinders state and local efforts. U.S. Department of Transportation (DOT), U.S. Census Bureau, and the Transportation Research Board require adequate funding and private-sector cooperation.

The second issue is to continue research into understanding and quantifying the public cost trade-offs between shipping freight by truck and by rail. As the highway system becomes increasingly congested and rail rates continue to rise, there will continue to be new legislative proposals to invest public funds in rail infrastructure, to strengthen rate regulation, and to pro-

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[2] And while these measures may be politically challenging, in economic terms, they are more efficient and are only a transfer of costs from one segment of society to another.

tect regional and short-line railroads. While railroads have been heavily researched in the past, continuing research into improving knowledge regarding the external cost trade-offs between modes is needed. Future research should include developing a more accurate comparison of rail and truck freight transportation costs and a model that can be used to explore different policy options, such as congestion tolls, carbon taxes, and the proposed rail-infrastructure tax credit. Capturing the relative congestion externalities will require developing improved economic modeling of decisionmaking in the freight transport industry as well as large-scale modeling of the nation's multimodal transportation network.

The third issue is to develop and implement a comprehensive national freight transportation strategy. DOT developed a draft freight transportation strategy in 2006 that began to address railroad transportation, but it was vague and was never developed into a major policy document (DOT, 2006). In addition, recent legislative efforts to address railroad infrastructure policy have been disjointed and industry driven.[3] A detailed and comprehensive plan is needed to provide guidance to DOT and to state departments of transportation that will better ensure that the right amount of investment in railroad infrastructure is invested in the right locations to optimize net social welfare. If public money is going to be used to subsidize private railroad investment, then there should be a better understanding of the costs and benefits that are going to accrue to the public. In passing the Staggers Rail Act (P.L. 96-448), the government did not abdicate all responsibility for regulating the railroad industry, which will always have some market imperfections. Surface-transportation advocates appear to agree that some federal funding of rail capacity expansion will be necessary. DOT should continue to improve its intermodal planning functions to ensure that this investment benefits the public interest.

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3 For instance, the Freight Rail Infrastructure Capacity Expansion Act (U.S. Senate, 2007).

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