National Rail Freight Infrastructure Capacity and Investment Study

prepared for

Association of American Railroads

by

Cambridge Systematics, Inc.

September 2007

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100 Cambridge Park Drive, Suite 400
Cambridge, Massachusetts 02140

date

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Executive Summary

This study is an assessment of the long-term capacity expansion needs of the continental U.S. freight railroads. It provides a first approximation of the rail freight infrastructure improvements and investments needed to meet the U.S. Department of Transportation's (U.S. DOT) projected demand for rail freight transportation in 2035. The U.S. DOT estimates that the demand for rail freight transportation—measured in tonnage—will increase 88 percent by 2035.

The study was commissioned by the Association of American Railroads (AAR) at the request of the National Surface Transportation Policy and Revenue Study Commission. The Commission is charged by Congress to develop a plan of improvements to the nation's surface transportation systems that will meet the needs of the United States for the 21st century.

The study focuses on 52,340 miles of primary rail freight corridors, which carry the preponderance of rail freight traffic.[1] These corridors, which constitute about one-third of all continental U.S. rail freight miles, are expected to absorb the bulk of the forecast traffic and nearly all of the investment to expand capacity.

The study estimates the need for new tracks, signals, bridges, tunnels, terminals, and service facilities in the primary corridors. The study does not estimate the cost of acquiring additional land, locomotives, and freight cars, or the cost of replacing and updating existing track, facilities, locomotives, and freight cars. The study assumes no shift in modal tonnage shares among rail, truck, and water beyond those projected by the U.S. DOT.

The study does not forecast passenger rail demand or estimate future passenger rail capacity needs; however, capacity is provided for the long-distance Amtrak and local commuter passenger rail services that are currently operated over rail freight lines. Additional investment, beyond that projected in this report, will be needed if the freight railroads host increased levels of passenger rail service. The Commission has convened a passenger rail committee that is studying the need for improvements and investments to support passenger rail demand through 2035. The findings of that committee will be reported separately.

This study estimates that an investment of $148 billion (in 2007 dollars) for infrastructure expansion over the next 28 years is required to keep pace with economic growth and meet the U.S. DOT's forecast demand. Of this amount, the Class I freight railroads' share is projected to be $135 billion and the short line

[1] Nearly all of these primary corridor miles are owned and operated by the seven Class I freight railroads: BNSF Railway, Canadian National (Grand Trunk Corporation), Canadian Pacific (Soo Line), CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. There are more than 550 short line and regional freight railroads.

and regional freight railroads' share is projected to be $13 billion. Without this investment, 30 percent of the rail miles in the primary corridors will be operating above capacity by 2035, causing severe congestion that will affect every region of the country and potentially shift freight to an already heavily congested highway system.

The investment requirement is driven by three factors: demand, current system capacity, and infrastructure expansion costs. The U.S. DOT estimates that population growth, economic development, and trade will almost double the demand for rail freight transportation by 2035. The projected rate of growth over the next 30 years is not extraordinary, but it comes after two decades of growth in rail freight tonnage that has absorbed much of the excess capacity in the existing rail freight system. Most of the moderate-cost capacity expansions have already been made; future capacity expansions will be purchased at a higher cost because they will require expensive new bridges and tunnels and more track and larger terminals in developed areas.

Meeting the U.S. DOT's forecast demand will require the Class I freight railroads to increase their investment in infrastructure expansion. The Class I railroads anticipate that they will be able to generate approximately $96 billion of their $135 billion share through increased earnings from revenue growth, higher volumes, and productivity improvements, while continuing to renew existing infrastructure and equipment. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads will be less able to meet the U.S. DOT's forecast demand.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

In summary, the findings point clearly to the need for more investment in rail freight infrastructure and a national strategy that supports rail capacity expansion and investment.

1.0 Objective

The objective of this study is to identify rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. Department of Transportation's (U.S. DOT) projected demand for rail freight transportation in 2035. The U.S. DOT estimates that the demand for rail freight transportation—measured in tonnage—will increase 88 percent by 2035. This projected rate of growth over the next 30 years is not extraordinary, but it comes after two decades of growth in rail freight tonnage that has absorbed much of the excess capacity in the existing rail freight system. The study assumes no shift in modal tonnage shares among rail, truck, and water beyond those projected by the U.S. DOT.

The study looks at infrastructure improvements that expand the capacity of rail lines, bridges, tunnels, terminals, and service facilities along the 52,340 miles of primary rail corridors within the U.S. owned and operated primarily by the seven Class I railroads—BNSF Railway, Canadian National (Grand Trunk Corporation), Canadian Pacific (Soo Line), CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. These primary corridors constitute about one-third of all U.S. rail miles and carry the preponderance of rail freight traffic.

The investment estimates include capital costs for expansion only; that is, the cost of the new rail lines and support facilities needed to accommodate future demand. The estimates do not include costs to maintain and operate the new rail lines and support facilities; acquire additional locomotives and railcars to provide services; or operate, maintain, and replace existing rail lines and facilities. Finally, the study does not include the costs to rail shippers to accommodate growth in rail traffic volumes at their facilities. The study does include a general estimate of the investment required to bring the weight-bearing capacity of Class I branch lines and short line and regional railroad lines up to current standards.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

2.0 Background

The study was done at the request of the National Surface Transportation Policy and Revenue Study Commission. The Commission was established by Congress in 2005 to provide a national vision and recommendations that will "preserve and enhance the surface transportation system to meet the needs of the United States for the 21st century."[2] The Commission is charged with completing a comprehensive study of the national surface transportation system and the Highway Trust Fund, then developing a conceptual plan with alternative approaches to ensure that the system continues to serve the needs of the United States.

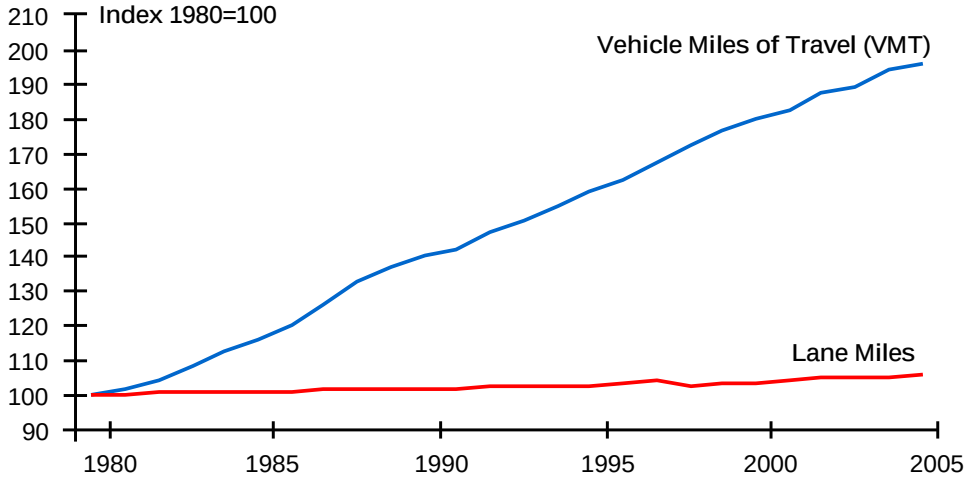
Since May 2006, the Commission has met regularly to hear about the challenges facing America's surface transportation network. The Commissioners have heard testimony from national transportation advocates, policymakers, industry, labor, and the general public. Congress is actively following the activities of the Commission, and the Commission's report (anticipated in December 2007) is expected to provide information that will be helpful to Congress as it considers reauthorization of the Federal surface transportation programs in 2009.

Over the course of its hearings, the Commission has expressed concern about the capacity and future of the nation's freight transportation systems. Freight transportation is vitally important to domestic economic productivity, the international competitiveness of American businesses, and the economic well-being of all Americans.

The demand for transportation is pressing the capacity of the nation's transportation systems, especially its critical highway and rail freight transportation infrastructure. On the highway system, vehicle-miles of travel grew by 96 percent between 1980 and 2005, while lane miles of road increased by only 5.7 percent. Figure 2.1, based on Federal Highway Administration (FHWA) statistics, illustrates the widening gap between vehicle-miles of travel and roadway capacity.

[2] See Section 1909 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU).

Figure 2.1 Vehicle Miles of Travel and Lane Miles
1980 to 2005



Source: Federal Highway Administration, *Highway Statistics*.

The result has been increasing highway congestion. The Texas Transportation Institute reports that over the decade between 1993 and 2003, the cost of highway congestion in the nation's urban areas increased from $39.4 billion to $63.1 billion, an increase of 60.2 percent.[3] The U.S. DOT estimates that the cost of congestion across all modes of transportation could be three times as high—approaching $200 billion per year—if productivity losses, costs associated with cargo delays, and other economic impacts are included. These include losses accruing to auto drivers, freight carriers, businesses, consumers, and the general public.[4]

As the cost of highway congestion has increased, public policy-makers at all levels of government have started looking to the railroads to carry more freight to relieve truck and highway congestion, and to help conserve energy, reduce engine emissions, and improve safety. Shippers, too, have started looking to railroads to carry more longer-distance shipments, especially as the costs of truck fuel and labor have increased.

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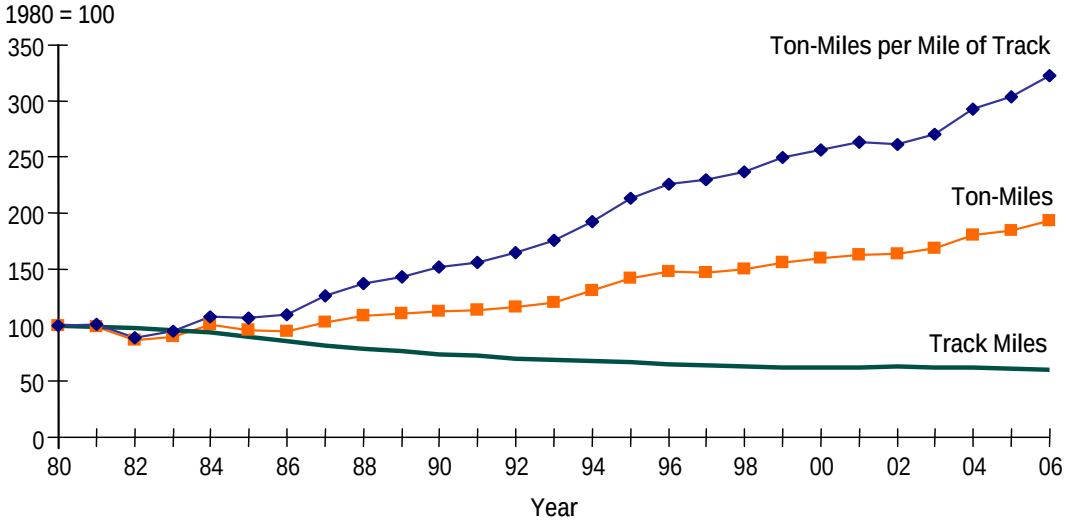
[3] David Schrank and Tim Lomax, *The 2005 Urban Mobility Report*, Texas Transportation Institute, May 2005, available at http://mobility.tamu.edu.

[4] U.S. Department of Transportation, *National Strategy to Reduce Congestion on America's Transportation Network*, Washington, D.C., March 2007.
See http://www.fightgridlocknow.gov/docs/conginitoverview070301.htm.

However, the growing demand for freight transportation is also pressing the capacity of the nation's rail freight system. Ton-miles of rail freight (one ton of freight moved one mile counts as one ton-mile) carried over the national rail system have doubled since 1980, and the density of train traffic—measured in ton-miles per mile of track—has tripled since 1980. Figure 2.2 illustrates the widening gap between ton-miles of rail travel and track miles.[5]

Figure 2.2 Rail Freight Ton-Miles and Track Miles
Class I Railroads, 1980 to 2006

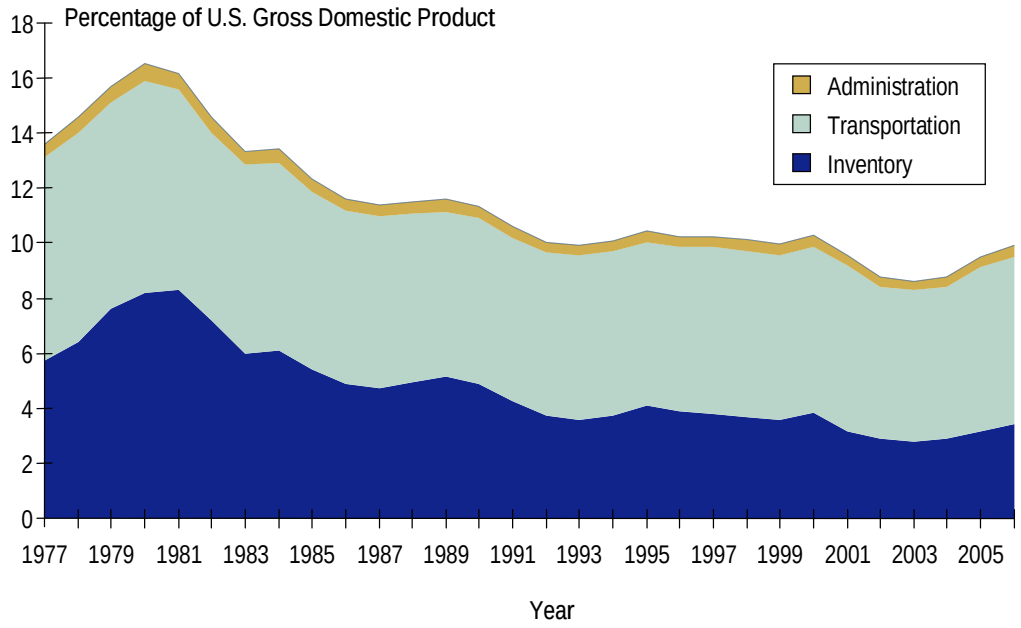


Source: AAR and Annual Report Form R-1.

The tightening of system capacity across all modes of freight transportation has likely contributed to the first notable increase in total logistics cost in over 25 years. Total logistics cost is the cost of managing, moving, and storing goods. Figure 2.3 shows the total logistics cost as a percentage of the U.S. gross domestic product (GDP).

[5] Association of American Railroads data and Annual Report Form R-1.

Figure 2.3 Total Logistics Cost
Percentage of Gross Domestic Product



Source: *State of Logistics Report*, Council of Supply Chain Management Professionals, 2006.

Logistics costs rose through the 1970s to a high of about 16 percent of GDP in 1980, reflecting rising fuel prices, increasing interest rates, and deteriorating productivity across the freight transportation system. Renewed investment in highways, economic deregulation of the freight transportation industry in the early 1980s, adoption of new technologies, and lower interest rates drove down the costs of truck, rail, air, and water freight transportation. The total logistics cost declined through the 1980s and 1990s to a low of about 8.6 percent of GDP in 2003. Businesses and consumers benefited because lower transportation costs resulted in lower-cost goods and better access to global markets.

But the total logistics cost is rising again. In 2006, the total logistics cost was 9.9 percent of GDP.[6] The change reflects recent increases in fuel prices and increases in congestion on the nation's highways and rail lines and at its international trade gateways and ports. Freight shippers and carriers are worried that the productivity of the nation's freight systems may continue to drop and that logistics costs may rise further, undermining future domestic economic productivity, international competitiveness, and economic growth.

[6] Rosalyn A. Wilson, *State of Logistics Report*, Council of Supply Chain Management Professionals, 2006 and 2007.

Freight shippers and carriers are especially concerned about the future capacity and productivity of the freight system because the demand for freight transportation is projected to nearly double by 2035. The U.S. DOT Freight Analysis Framework (FAF Version 2.2) estimates that the demand for freight transportation will grow from 19.3 billion tons today to 37.2 billion tons in 2035, an increase of about 93 percent.[7]

To absorb this growth and maintain their existing shares of the freight transportation market, the nation's truck and rail freight systems must increase their capacity and productivity substantially. Trucks and the highway system must add capacity to handle 98 percent more tonnage. And railroads must add capacity to handle 88 percent more tonnage. The U.S. DOT estimates assume no shift in modal tonnage shares among rail and truck beyond those created by structural changes in the economy (i.e., different growth rates across freight-generating industries).

The anticipated rates of growth for the U.S. economy and freight transportation demand are about the same as those experienced over the last 30 years; however, much of the capacity existing or created over those years has been filled, leaving the nation with a need to provide new capacity through expanded infrastructure and improved productivity.[8]

Figure 2.4 shows the relative shares of freight—measured in ton-miles—carried by truck and rail in 2005.[9] If railroads cannot carry their share in 2035, then freight will be shed to trucks and an already heavily congested highway system. Conversely, if trucks cannot carry their share in 2035, then freight must be shifted to rail and the capacity of the rail system expanded even more than currently forecast.

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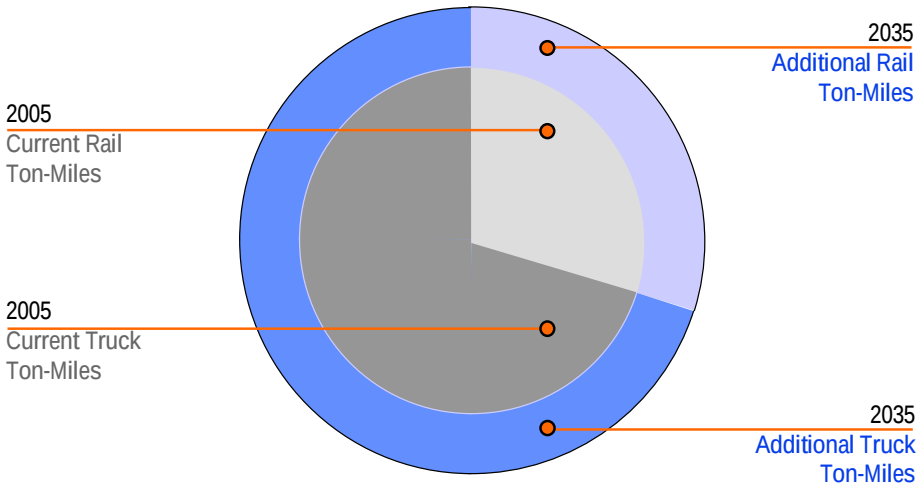
[7] See U.S. Department of Transportation, Freight Analysis Framework, *Freight Facts and Figures* at http://www.ops.fhwa.dot.gov/freight/. This study uses the current Freight Analysis Framework (FAF Version 2.2) forecasts.

[8] Global Insight, Inc. forecasts that the U.S. economy will grow at a compound annual rate of about 2.8 percent over the next 30 years. Source: Global Insight, Inc. in *Freight Demand and Logistics Bottom Line Report* prepared by Cambridge Systematics, Inc. for the American Association of State Highway and Transportation Officials (AASHTO), (forthcoming, 2007).

[9] Ton-miles estimated by Global Insight for the AASHTO *Freight Demand and Logistics Bottom Line Report*.

Figure 2.4 Truck and Rail Market Shares in Ton-Miles
2005 and 2035



Source: Cambridge Systematics, Inc., based on Global Insight, Inc. freight demand forecasts.

In response to these projections and concerns, the Commission asked the Association of American Railroads (AAR) to assess the capacity of the nation's rail system to accommodate the estimated increase in freight-rail traffic. The AAR, supported by the four largest Class I railroads—the BNSF Railway, CSX Transportation, the Norfolk Southern Corporation, and the Union Pacific Railroad—undertook this study to estimate the additional rail freight capacity and investment required to meet the U.S. DOT forecast.

This study is a hallmark study, the first effort of its kind. The U.S. DOT and the Federal Highway Administration (FHWA) have developed national infrastructure needs and cost estimates for the publicly owned highway systems, but no comparable, long-term, national estimates have been developed for the rail system. The railroads are publicly traded or privately owned companies, and the planning horizons for railroad capital projects typically do not extend out 30 years. And neither the U.S. DOT nor individual state DOTs have comprehensive rail infrastructure databases suitable for long-term planning. This study is the first collective assessment by the major freight railroads of their long-term capacity expansion and investment needs.

3.0 Methodology

This study provides a first approximation of the rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. DOT's projected demand for rail freight transportation in 2035. It addresses two major rail freight infrastructure elements:

- Line expansion:
  - Upgrades to the Class I railroad system mainline tracks and signal control systems;
  - Improvements to significant rail bridges and tunnels;[10]
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad tracks and bridges to accommodate 286,000-pound freight cars.[11]
- Facility expansion:
  - Expansion of carload terminals, intermodal yards, and international gateway facilities owned by railroads; and
  - Expansion of Class I railroad service and support facilities such as fueling stations and maintenance facilities.

[10] Included in this category are expansions of major bridges and tunnels (or construction of new parallel bridges and tunnels) to add rail capacity along a corridor, and corridor overhead clearance projects, which typically involve raising dozens of highway bridges crossing a rail line to permit the movement of double-stacked intermodal container trains.

[11] Most Class I railroad tracks and bridges have been designed or reconstructed to carry railcars weighing 286,000 pounds, and some Class I lines accommodate railcars weighing up to 315,000 pounds. Older rail lines, including some Class I railroad secondary mainlines and branch lines and about half of the short line and regional railroad tracks and bridges, were designed and constructed to carry railcars weighing up to 263,000 pounds. The heavier, "standard," 286,000-pound cars can be operated over many lines designed for lighter cars, but usually at very low speeds.

The study includes the cost of designing and constructing these improvements, but does not include the cost of acquiring real estate to accommodate new rail lines and terminals.[12] This is consistent with the approach used in national highway system needs and investment studies, which do not estimate the cost of acquiring real estate for widening or adding highways. The study does not include the cost of capital depreciation or the cost of buying additional locomotives and rail cars to expand service. Railroad maintenance and operating costs are not included, for either existing or expanded lines and facilities.

The study assumes that capacity is provided for long-distance Amtrak and local commuter passenger rail services that are currently operated over rail freight lines, but the study does not forecast the need for new passenger rail services or the necessary capacity to support passenger rail growth. The Commission has convened a passenger rail committee that is studying the need for improvements and investments to support passenger-rail demand through 2035. The findings of that committee will be reported separately.

This study estimates rail line capacity and investment requirements by:

- Dividing the continental U.S. Class I railroad network into primary corridors;
- Establishing current corridor volume in freight and passenger trains per day for each primary corridor, based on 2005 Surface Transportation Board Carload Waybill data, the most recent comprehensive information available;
- Estimating current corridor capacity in trains per day for each primary corridor, based on current information;
- Comparing current corridor volume to current corridor capacity;
- Estimating future corridor volume in trains per day, using U.S. DOT's Freight Analysis Framework Version 2.2 forecasts of rail freight demand in 2035 by type of commodity and by the origin and destination locations of shipments moving within the U.S. and through international land and port gateways;
- Comparing the future corridor volume to current corridor capacity;

[12] Current capital expenditures by the Class I railroads for expansion of lines and terminals (as reported in Section 4.5) include the cost of acquiring real estate. However, with the exception of land acquired for new or expanded intermodal terminals, the cost of real estate acquisition has been a small part of current capital expenditures because most new rail lines have been constructed within existing railroad-owned rights-of-way. As the space in existing rights-of-way is used up, the cost of acquiring real estate for new lines is expected to be a larger percentage of capital expenditures for expansion. The real estate costs will be in addition to the infrastructure costs estimated in this study.

- Determining the additional capacity needed to accommodate future train volumes at an acceptable level of service reliability;
- Identifying the rail line and signal control system improvements required to provide the additional capacity; and
- Estimating the costs of the improvements.

The study estimates the need for expansion of Class I railroad carload terminals, intermodal yards, and railroad-owned international gateway facilities by analyzing the projected increases in the number of railcars and intermodal units (containers and truck trailers) handled at major facilities and comparing them to current handling capacity. Expansion costs are estimated using unit costs per railcar or intermodal container, or estimated using recent and comparable terminal expansion project costs. Estimates of the cost of expanding service and support facilities such as fueling stations were provided by the railroads based on the anticipated changes in the number and type of trains.

Finally, the study estimates the capacity and investment requirements for secondary mainlines, branch lines, and short line and regional railroads by updating information from a prior study of short line system investment needs commissioned by the American Short Line and Regional Railroad Association.[13]

Wherever possible, the analysis is based upon existing and publicly available data sources. The key sources of data are the following:

- Oak Ridge National Laboratory (ORNL) Center for Transportation Analysis' Rail Network (Version 5-5) is used to develop a primary corridor network model and identify the key corridor characteristics such as the number of tracks and type of signal system;
- The U.S. DOT Surface Transportation Board's (STB) 2005 Carload Waybill Sample is used to estimate current corridor volumes based on 2005 loaded-car movements;
- Data from the Surface Transportation Board's Uniform Rail Costing System (URCS) on empty-return ratios by railroad, car type, and car ownership are used to estimate empty car movements;
- The U.S. DOT's Freight Analysis Framework (FAF Version 2.2) forecast is used to establish rail freight traffic growth by type of train service (e.g., intermodal train, manifest/carload train, auto train, and bulk train) from 2005 to 2035;

[13] Zeta-Tech Associates, Inc., *An Estimation of the Investment in Track and Structures Needed to Handle 286,000-Pound Rail Cars*, prepared for the American Short Line and Regional Railroad Association, May 26, 2000.

- Data from the railroads and the AAR are used to estimate the capacity in trains per day for archetypical rail corridors representing different combinations of number of tracks and signal types. The capacities of the archetypical rail corridors are used to identify the improvements needed to accommodate future train volumes.
- Data from the Class I railroads, the AAR, and published construction industry information are used to estimate the cost of adding tracks, upgrading signal systems, expanding terminals, and adding rail-support facilities.

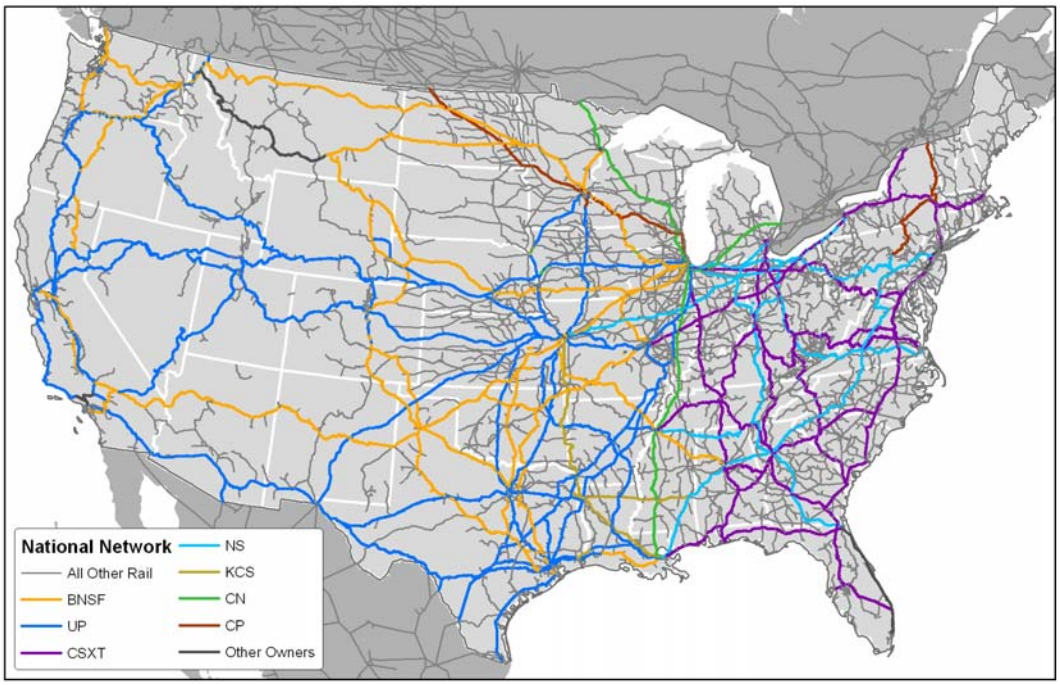
Appendix A describes the technical methodology in more detail.

4.0 Current Train Volumes and Capacity

4.1 PRIMARY CORRIDORS

The study focuses on the primary rail corridors within the national rail freight system. Figure 4.1 shows the national rail network. The primary corridors for each of the seven Class I railroads are shown in color; all other rail lines are shown in gray.

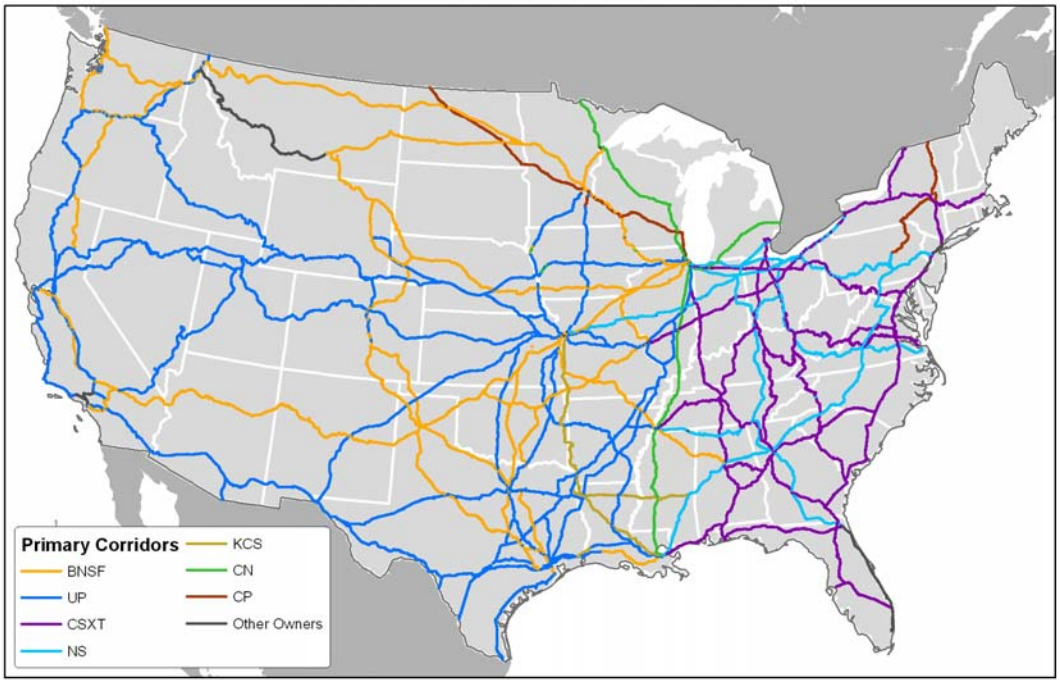
Figure 4.1 National Rail Freight Network and Primary Rail Freight Corridors



Source: Cambridge Systematics, Inc.

Figure 4.2 shows just the primary corridors used for this study of rail freight capacity. The primary corridors were designated by the Class I railroads for this study. The primary corridors represent the higher-volume corridors for rail freight. The primary corridors total about 52,340 miles of road (or centerline miles), representing about half of all Class I-operated miles in the U.S. and about one-third of the 140,810 miles in the U.S. rail freight network. For comparison, the Interstate Highway System comprises about 47,000 route miles, and the National Highway System, which adds other major U.S. and state freight highways, comprises about 162,000 route miles.

Figure 4.2 Primary Rail Freight Corridors



Source: Cambridge Systematics, Inc.

4.2 CURRENT VOLUMES

Current corridor volumes in trains per day were established for each primary corridor using data from the Surface Transportation Board's 2005 Carload Waybill Sample. The Waybill Sample is an annual survey of railcar movements on the national rail network. The survey collects information from a sample of loaded, revenue-producing railcar movements. The data include information about the commodity shipped, the type of railcar used, the origin and destination station of the shipment, any interchanges between railroads, and the names of railroads handling the shipment. The sample data are statistically expanded to represent 100 percent of the loaded revenue railcar moves in a year. The Waybill Sample is used in many regulatory proceedings and is generally considered an accurate reflection of U.S. railroad shipments. The 2005 Waybill Sample is the most recent comprehensive data available.

The Waybill Sample does not collect information about empty, non-revenue-producing railcar movements. These were estimated using information from the Uniform Rail Costing System (URCS) on empty-return ratios by railroad, car type, and car ownership. The number of empty, non-revenue-producing railcar movements were added to the number of loaded, revenue-producing railcar movements to estimate total railcar movements.

The number of carloads moving on the rail system varies daily, weekly, and seasonally. To select a representative day, the distribution of the number of carload movements for each day in 2005 was examined and the volume for the 85th percentile day was selected for analysis. This approach is consistent with the analysis procedures for highway needs studies.

The carload volumes were then allocated among four types of train service based on the commodity being carried and the type of operation:

1. **Auto Train Service –** For assembled automobiles, vans, and trucks moving in multilevel cars;
2. **Bulk Train Service –** For grain, coal, and similar bulk commodities moving in unit trains;
3. **Intermodal Train Service –** For commodities moving in containers or truck trailers on flat cars or specialized intermodal cars; and
4. **General-Merchandise Train Service –** Everything else, including commodities moved in box cars and tank cars.

The number of trains of each type needed to move the cars were estimated using information on the typical number of cars hauled by train service type, as summarized in Table 4.1. The number of intermodal trains needed is based on the number of intermodal units (e.g., container-on-flat-car [COFC] units and trailer-on-flat-car [TOFC] units). Separate calculations were made for Eastern and Western Class I railroads because differences in regional geography and topography allow Western railroads to operate longer trains.[14]

Table 4.1 Typical Number of Cars or Intermodal Units by Train Service Type

Type of Train Service	Eastern Railroads	Western Railroads
Auto	57.0	63.9
Bulk	86.0	112.4
General Merchandise	82.0	80.7
Intermodal (TOFC/COFC count)	110.7	164.3

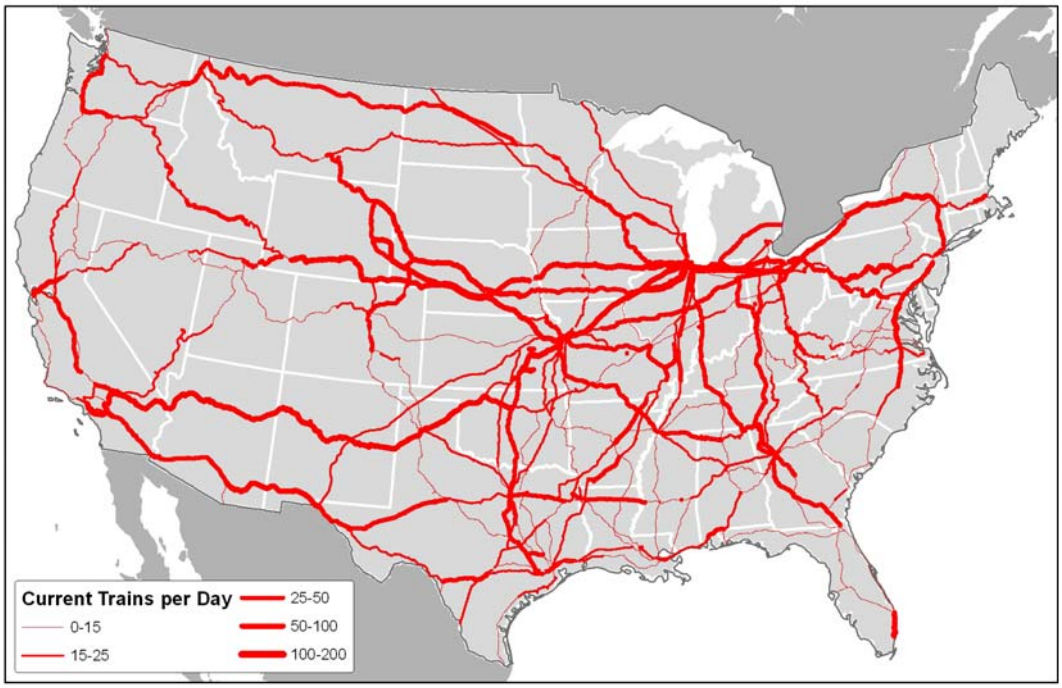
Source: Class I railroad data.

[14]For details, see Appendix A.

Finally, the number of long-distance Amtrak and local commuter passenger rail trains operating over the primary rail freight corridors was added to the number of freight trains to calculate the total number of trains per day per corridor. The number of passenger trains was estimated from published information on Amtrak and commuter passenger rail schedules for 2007.

Figure 4.3 maps the current corridor volumes in trains per day for the primary rail freight corridors. The number of trains per day is indicated by the width of the corridor line. The thinnest line indicates that a corridor carries up to 15 trains per day; the widest line indicates that a corridor carries between 100 and 200 trains per day.

Figure 4.3 Current Corridor Volumes by Primary Rail Freight Corridor
2005 Freight Trains and 2007 Passenger Trains per Day



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

4.3 CURRENT CAPACITY

To determine whether a corridor is congested, current volume was compared to current capacity. Three variables were used to estimate the current capacity of the primary corridors: the number of tracks, the type of control system, and the mix of train types.[15]

- **Tracks –** Most sections of the national rail freight system are single-tracked with multiple sidings for trains to meet and pass each other, and a significant portion of the heaviest-volume corridors are double-tracked. A limited number of sections have three or four tracks.
- **Control System –** The type of control system affects capacity by maintaining a safe spacing between trains meeting and passing on the same track. There are three major types of signal systems:
  - **Automatic Block Signaling (ABS)** is a signal system that controls when a train can advance into the next track block. A block is a section of track with traffic control signals at each end. The length of the block is based on the length of a typical train and the distance needed to stop the train in a safe manner. When a train exits a block, the signal changes to yellow, indicating to the engineer of a following train that the block is now empty, but that the following train should be prepared to stop before entering the next block (currently occupied by the train ahead). Automatic block signaling is governed by block occupancy and cannot be controlled by a railroad dispatcher from a remote location.
  - **Centralized Traffic Control (CTC)** and **Traffic Control System (TCS)** are systems that use electrical circuits in the tracks to monitor the location of trains, allowing railroad dispatchers to control train movements from a remote location, typically a central dispatching office. CTC and TCS increase capacity by detecting track occupancy and allowing dispatchers to safely decrease the spacing between trains because the signal systems automatically prevent trains from entering sections of track already occupied by other trains.
  - **No Signal (N/S)** and **Track Warrant Control (TWC)** are basic train control systems that require the train crew to obtain permission or warrants

[15] The capacity of rail corridors is determined by a large number of factors, including the number of tracks, the frequency and length of sidings, the capacity of the yards and terminals along a corridor to receive the traffic, the type of control systems, the terrain, the mix of train types, the power of the locomotives, track speed, and individual railroad operating practices. Complete, consistent, and current information on all these factors was not available for the study, so the capacity of the primary corridors was estimated using only the three dominant factors (e.g., number of tracks, type of signal system, and mix of train types).

before entering a section of track. Crews receive track warrants by radio, phone, or electronic transmission from dispatcher. TWC is used on low-volume track instead of more expensive ABS or CTC/TCS systems.

- **Train Types –** The mix of train types determines the speed and spacing of trains on a track. Different types of trains operate at different speeds and have different braking capabilities. A corridor that serves a single type of train will usually accommodate more trains per day than a corridor that serves a mix of train types. Trains of the single type can be operated at similar speeds and with more uniform spacing between the trains because they have similar braking capabilities. This increases the total number of trains that can traverse the corridor per day. When trains of different types—each with different length, speed, and braking characteristics—use a corridor, greater spacing is required to ensure safe braking distances. As a result, the average speed drops, reducing the total number of trains that can traverse the corridor per day. For the study, trains were grouped into three train-type groups based on their operating characteristics:
  - **Train-Type Group 1 –** includes merchandise/carload trains and bulk coal and grain trains. These trains tend to haul heavier, bulkier commodities such as coal, grain, gravel, and phosphates, and operate at slower speeds.
  - **Train-Type Group 2 –** includes intermodal trains and multilevel auto carriers hauling assembled automobiles. These trains tend to operate at higher speeds because they are lighter than merchandise and bulk trains and are run to more exacting schedules.
  - **Train-Type Group 3 –** includes passenger trains such as Amtrak's long-distance trains and local commuter rail trains. Passenger trains operate at high speeds and on fixed schedules, similar to the speeds and schedules of intermodal trains. They require close control to ensure safe operation and stopping distances, especially when operating along corridors carrying merchandise trains or a mix of merchandise and intermodal trains. By law, Amtrak passenger trains operating over rail freight lines must be given priority; this means that when Amtrak trains meet or overtake freight trains, the freight trains are shunted to sidings or parallel lines until the passenger train has passed.

There are eight combinations of number of tracks and type of signal system that are in common use across the primary corridors today. Table 4.2 lists the combinations, along with five- and six-track corridor types, which are used in this study to accommodate future demand. The first column lists the number of tracks, and the second column lists the type of control system. For each combination of number of tracks and type of control system, the maximum number of trains that can typically be accommodated is determined by the mix of train types operating along the corridor. The third column in the table lists the maximum practical capacity in trains per day that can be accommodated if multiple train types (e.g., merchandise, bulk, and passenger trains) use the corridor. The

rightmost column lists the maximum practical capacity in trains per day that can be accommodated if a single train type (e.g., all intermodal trains) uses the corridor.

Table 4.2 Average Capacities of Typical Rail-Freight Corridors
Trains per Day

		Trains per Day	
Number of Tracks	Type of Control	Practical Maximum If Multiple Train Types Use Corridor*	Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, a mix of merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

The table presents average capacities for typical rail freight corridors. The actual capacities of the corridors were estimated using railroad-specific capacity tables. At the request of the railroads, these detailed capacity tables were not included in this report to protect confidential railroad business information.

Source: Class I railroad data aggregated by Cambridge Systematics, Inc.

Typically, a corridor serving multiple train types will have a lower capacity than a corridor serving a single train type. For example, a railroad corridor with two tracks, a centralized traffic control (CTC) system, and a mix of merchandise/bulk trains, intermodal/auto trains, and passenger trains would typically operate at a capacity of about 75 trains per day. The same corridor, serving all merchandise trains, would typically operate at a capacity of about 100 trains per day.

For the study, each primary corridor in the national rail network was assigned a capacity based its actual number of tracks, type of control system, and mix of train types. The calculated capacity of each corridor was reviewed with the railroads. The railroads made adjustments to update network information and better represent their actual corridor train volumes and capacities.

4.4 CURRENT VOLUMES COMPARED TO CURRENT CAPACITY

Current corridor volumes were compared to current corridor capacity to assess congestion levels. This was done by calculating a volume-to-capacity ratio expressed as a level of service (LOS) grade. The LOS grades are listed in Table 4.3.

Table 4.3 Volume-to-Capacity Ratios and Level of Service (LOS) Grades

LOS Grade	Description		Volume/Capacity Ratio
A	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2
B			0.2 to 0.4
C			0.4 to 0.7
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
E	At Capacity	Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents	0.8 to 1.0
F	Above Capacity	Unstable flows; service breakdown conditions	> 1.00

Source: Cambridge Systematics, Inc.

Rail corridors operating at LOS A, B, or C are operating below capacity; they carry train flows with sufficient unused capacity to accommodate maintenance work and recover quickly from incidents such as weather delays, equipment failures, and minor accidents. Corridors operating at LOS D are operating near capacity; they carry heavy train flows with only moderate capacity to accommodate maintenance and recover from incidents. Corridors operating at LOS E are operating at capacity; they carry very heavy train flows and have very limited capacity to accommodate maintenance and recover from incidents without substantial service delays. Corridors operating at LOS F are operating above capacity; train flows are unstable, and congestion and service delays are persistent and substantial. The LOS grades and descriptions correspond generally to the LOS grades used in highway system capacity and investment requirements studies.

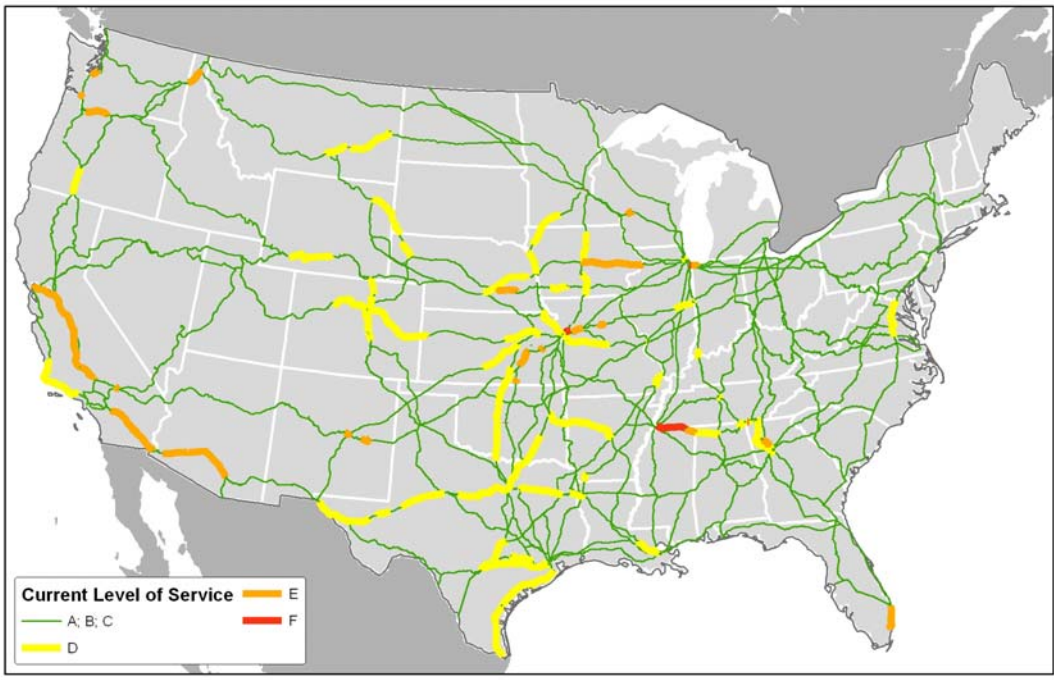
A rail corridor that is operating at a volume-to-capacity ratio of 0.7 (the boundary between LOS C and LOS D), is operating at 70 percent of its theoretical maximum capacity. This is considered to be the corridor's practical capacity because a portion of the theoretical maximum capacity is lost to maintenance, weather delays, equipment failures, and other factors. A corridor operating at LOS C will have stable train flows, ensuring that schedules can be met reliably and safely, and permitting timely recovery from service disruptions. At LOS D, a corridor will have stable operations under normal conditions, but service can quickly become unstable with unplanned and unanticipated disruptions. At volume-to-capacity ratios significantly greater than 0.8 (e.g., at LOS E or F), train flow rates and schedule reliability deteriorate and it takes longer and longer to recover from disruptions. To provide acceptable and competitive service to shippers and receivers, railroads typically aim to operate rail corridors at LOS C/D or better.

Figure 4.4 maps the volume-to-capacity ratios, expressed as LOS grades, for each primary rail corridor, based on current train volumes and current capacity.[16] For legibility, rail corridors operating at LOS A, B and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Analysis of the current levels of service, summarized in Table 4.4, shows that 88 percent of today's primary corridor mileage is operating below practical capacity (LOS A/B/C), 12 percent is near or at practical capacity (LOS D/E), and less than 1 percent is operating above capacity (LOS F).

[16] Current volumes are based primarily on shipment volumes reported in the 2005 STB Carload Waybill Sample. These volumes do not reflect fully recent increases in coal shipments moving from Western coal fields (e.g., Powder River Basin) to Eastern utilities nor the recent increases in intermodal containers delivered by water to East Coast ports and transferred to rail for inland delivery. Current capacity is based on 2007 information.

Figure 4.4 Current Train Volumes Compared to Current Train Capacity



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Table 4.4 Primary Rail Corridor Mileage by Current Level of Service Grade *Current Volumes and Current Capacity*

LOS Grade	Total Mileage	Percentage
A	9,719	19%
B	15,417	30%
C	20,683	39%
D	4,952	9%
E	1,461	3%
F	108	<1%
Totals	52,340	100%

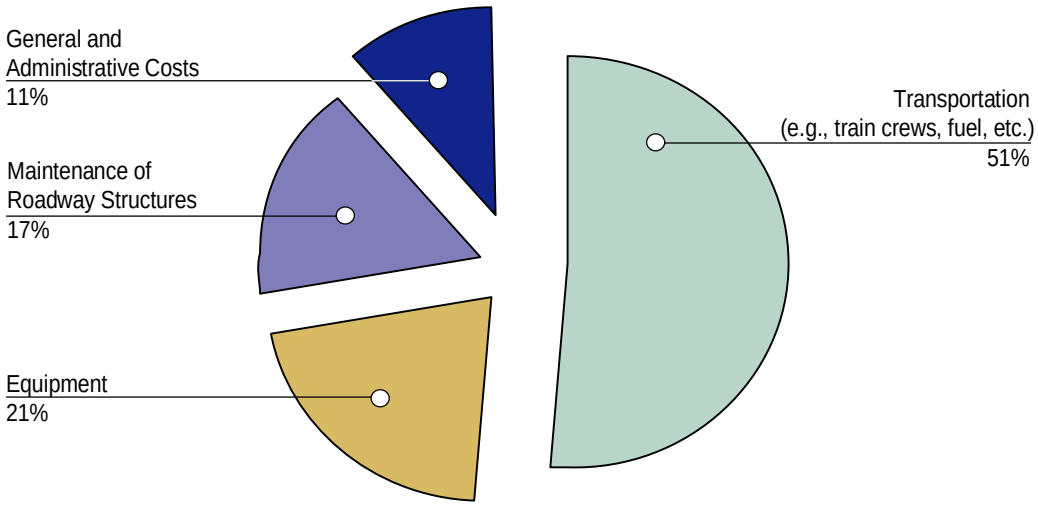
Source: Cambridge Systematics, Inc.

4.5 CURRENT RAILROAD INVESTMENT IN CAPACITY

The Class I railroads generated $52.2 billion in revenue in 2006 and incurred $41 billion in operating expenses.[17] After deducting interest charges, taxes and other miscellaneous items, the Class I railroads earned a net income of $6.5 billion in 2006.

Of the $41 billion in expenses, $21.1 billion (40 percent of revenue) was spent on transportation, which includes the costs of train crews and fuel; $8.5 billion (16 percent of revenue) on equipment; $6.8 billion (13 percent of revenue) on maintenance of roadway (e.g., rails, ties, ballast and substructure) and structures (e.g., bridges, tunnels, service building, etc.); and $4.6 billion (9 percent of revenue) on general and administrative costs. A breakdown of the operating expenditures is shown in Figure 4.5.

Figure 4.5 Class I Railroad Operating Expenditures
2006



Source: American Association of Railroads.

In 2006, the Class I railroads' capital expenditures totaled $8.5 billion. Of this, $1.5 billion (about 18 percent) was spent on equipment, and $7.0 billion (about

[17] In 2006, the operations and maintenance (O&M) cost for Class I railroads was $210,380 per mile of track and $359,097 per mile of road. This O&M cost is a fully burdened cost including transportation, equipment maintenance, G&A (but not maintenance of way and structures), and capital expenditures for equipment (but not way and structures). Depreciation is deducted to avoid double-counting. The calculations are based on 162,056 miles of operated track and 94,942 miles of road, less miles operated under trackage rights to avoid double-counting. This information is for the seven Class I railroads, U.S. operations only.

82 percent) on roadway and structures.[18] These capital expenditures include amounts for renewal of the existing roadway, structures, and equipment, as well as expenditures for expansion to serve additional traffic.

Combining operating and capital spending and adjusting for depreciation, 40 percent of the Class I railroads' revenue is spend on maintenance, replacement, or expansion of their track, structures, and equipment.[19] In 2006, the Class I railroads spent $10.6 billion maintaining and improving their infrastructure, and another $8.7 billion on equipment.[20]

The AAR estimates that the Class I railroads will spend approximately $1.9 billion in 2007 for expansion of capacity through the construction of new roadway and structures. This is the highest level of investment for expansion in recent years and reflects a steady increase in investment in expansion of roadway and structures. The Class I railroads invested $1.1 billion in expansion of roadway and structures in 2005. The Class I railroads invested $1.4 billion in infrastructure expansion in 2006. This was in addition to an expenditure of $17.9 billion for renewal of roadway, structures, and equipment and additions to locomotives and freight cars. The average annual investment in infrastructure expansion over the three year period from 2005 to 2006 was $1.5 billion per year.[21]

As these numbers demonstrate, rail transportation is capital intensive, requiring high levels of spending on infrastructure such as track, bridges, and signals; locomotives, freight cars, and maintenance equipment; and information technology. From 1996 through 2005, Class I railroad capital expenditures averaged 17 percent of revenue. (The comparable figure for the average U.S. manufacturer was 3 percent of revenue.) Railroad capital expenditures for ties alone have exceeded $1 billion every year since 2003, and spending for rail has been even higher.

Even though the railroads must invest heavily in infrastructure, the railroads have had substantial surplus capacity in the rail network for many years. This has enabled them to absorb traffic growth with relatively modest additional capital commitments to expand infrastructure. With this surplus capacity largely absorbed by two decades of growth and with major traffic increases in the past few years, an increasing portion of the capital investment in roadway and structures has been devoted to capacity expansion. And with traffic growth through 2035 expected to be significant, increasing amounts of capital will need to be devoted to expansion.

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[18] These capital expenditures do not include some equipment that was acquired under operating leases.

[19] Capital expenditures plus operating expenses for infrastructure and equipment, minus depreciation to avoid double-counting capital spending.

[20] Association of American Railroads economists estimate that each $1 billion of investment in rail infrastructure generates over 20,000 jobs.

[21] Association of American Railroads data.

5.0 Future Train Volumes and Capacity

5.1 FUTURE VOLUMES

2035 train volumes were projected using economic growth and commodity forecasts from the U.S. DOT's Freight Analysis Framework (FAF Version 2.2). The FAF forecasts are national freight transportation estimates covering all types of shipments by truck, rail, water, pipeline, and air. The U.S. DOT and the Federal Highway Administration use the FAF forecasts to analyze truck freight demand and help estimate highway capacity needs and investment requirements.

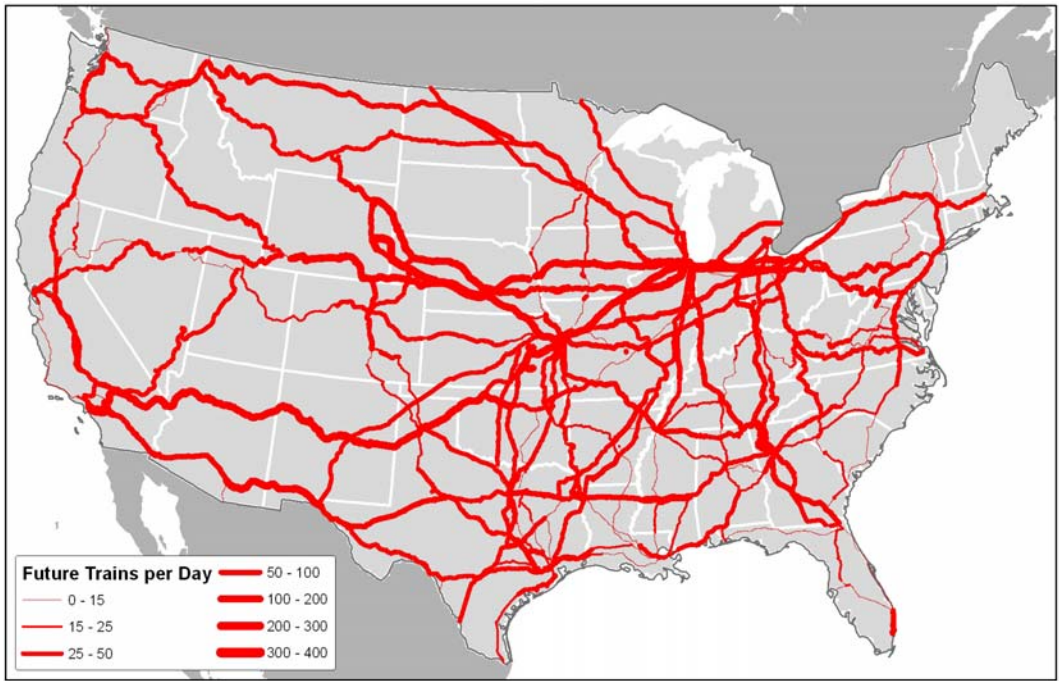
The FAF forecasts consider growth in population, the economy, and international trade. Forecasts of the demand for freight transportation are derived by examining production, consumption, and trade by major industry sector and economic region in the U.S., North America, and the rest of the world. The rail freight forecasts cover over 40 categories of commodities and estimate the volume of each type of commodity moving among 138 economic zones (114 zones representing economic areas and international trade gateways within the U.S., and 24 zones representing economic areas in Canada, Mexico, and overseas).

The forecasts are driven by demand only; they are not constrained by supply. This means that if an industry grows and the industry currently ships and receives a commodity by rail, then the industry will ship and receive more of that commodity by rail in the future. Conversely, if an industry declines and the industry currently ships and receives a commodity by rail, then the industry will ship and receive less by rail in the future. The forecasts assume that the rail system (and other freight modes) will have the capacity to meet the future demand. The forecasts also do not attempt to presuppose how markets and demand will change in response to future, but unknown, changes in technology, regulation, and politics. The forecasts are a starting point for consideration of the effect of future demand on infrastructure capacity and investment requirements, but are not comprehensive in their estimation of future freight demand.

The FAF Version 2.2 2035 commodity forecasts were used to develop weighted growth rates for the four types of train services—auto train service (for finished automobiles), bulk train service (for grain, coal, and similar bulk commodities), intermodal train service (for commodities moving in containers or truck trailer on flat cars or specialized intermodal cars), and general-merchandise train service (for everything else, including commodities moved in box cars and tank cars). The growth rates were applied to the number of 2005 trains to approximate the number of 2035 trains. The number of passenger trains was held at 2007 levels and added to the estimated number of freight trains in 2035.

Figure 5.1 maps the future corridor volumes in trains per day for the primary rail freight corridors. The number of trains per day is indicated by the width of the corridor line. The thinnest line indicates that a corridor carries up to 15 trains per day; the widest line indicates that a corridor carries between 300 and 400 trains per day.

Figure 5.1 Future Corridor Volumes by Primary Rail Freight Corridor
2035 Freight Trains and 2007 Passenger Trains per Day

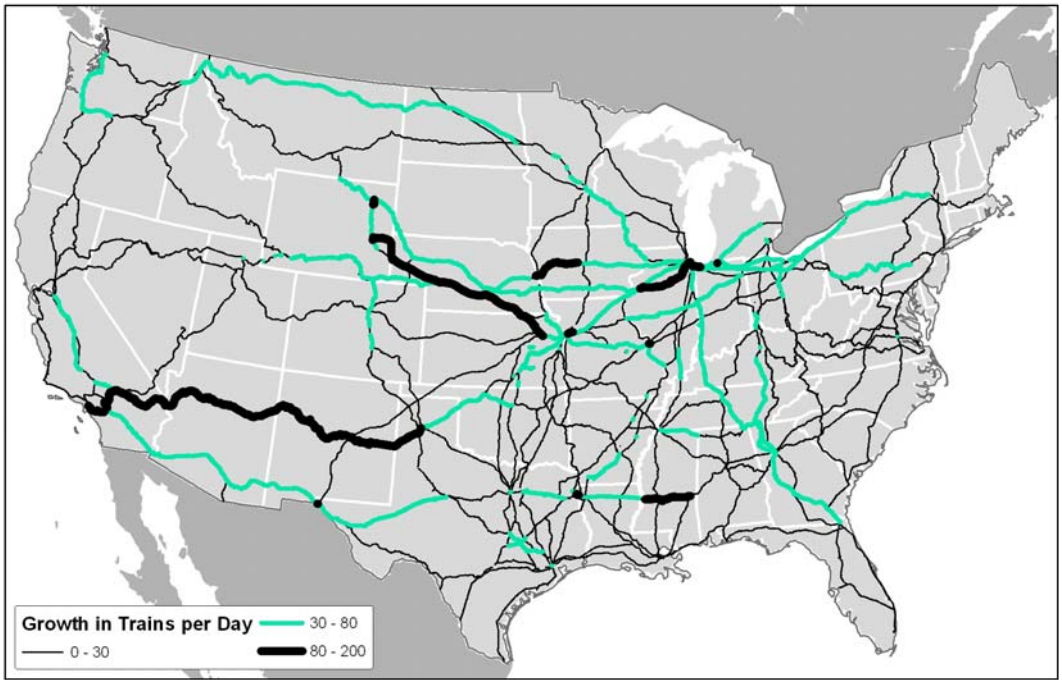


Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Figure 5.2 compares current and future volumes by primary corridor. The figure shows the growth in trains per day between the 2005 volumes and the 2035 volumes. The growth is indicated by the width and color of the corridor line. A thin black line indicates that a corridor will carry up to 30 additional trains per day by 2035; a green line indicates that a corridor will carry between 30 and 80 additional trains per day; and a thick black line indicates that a corridor will carry between 80 and 200 additional trains per day.

Figure 5.2 Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor

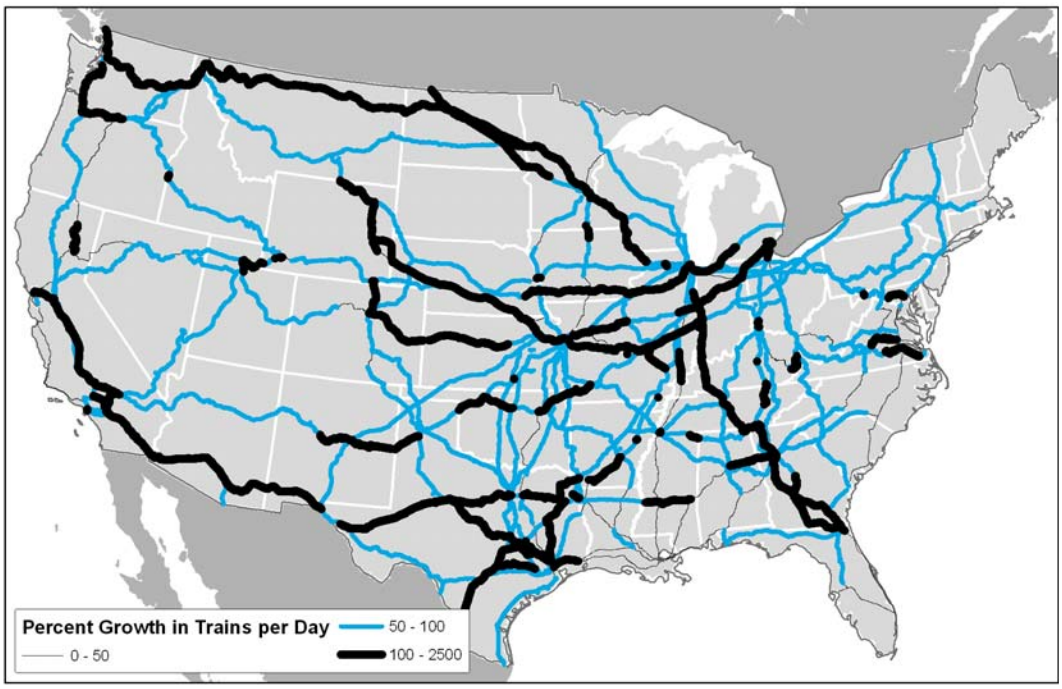


Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Figure 5.3 also compares current and future volumes by primary corridor, but the figure shows the percentage growth in trains per day from 2005 to 2035. The percentage growth is indicated by the width and color of the corridor line. A thin black line indicates that a corridor will carry up to 50 percent more trains per day by 2035; a blue line indicates that a corridor will carry between 50 and 100 percent more trains per day; and a thick black line indicates that a corridor will carry over 100 percent more trains per day.

Figure 5.3 Percentage Growth in Trains per Day from 2005 to 2035 by Primary Rail Corridor



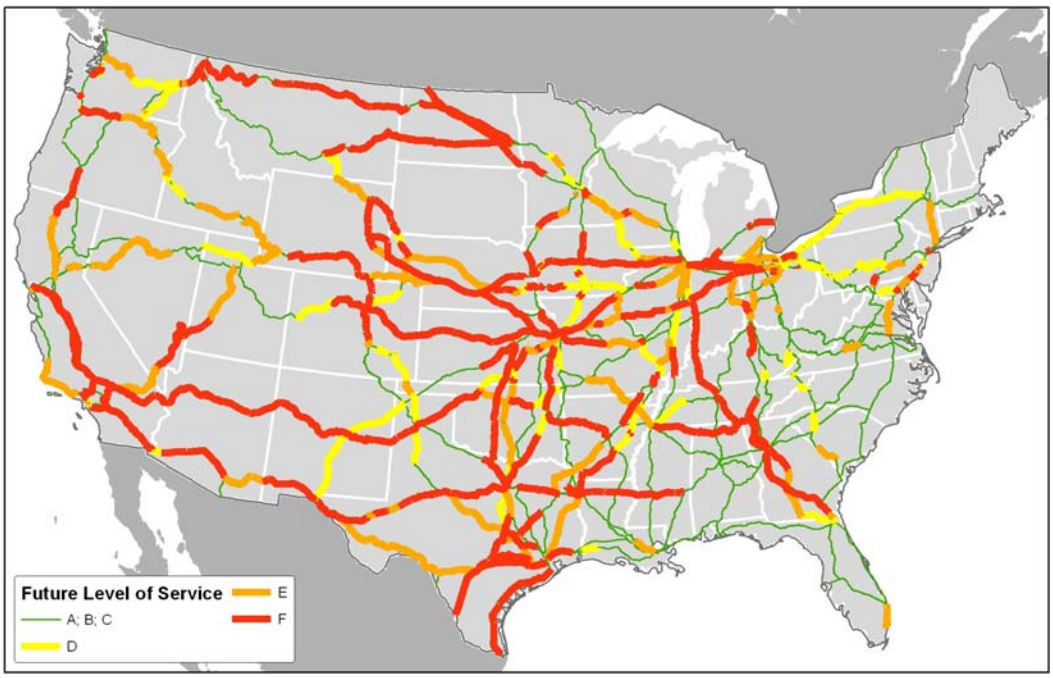
Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

5.2 FUTURE VOLUMES COMPARED TO CURRENT CAPACITY

Future volumes were compared to current capacity to estimate future volume-to-capacity ratios. This information was used to determine where demand will exceed capacity and where improvements will be required to avoid congestion. Figure 5.4 compares 2035 volumes in trains per day to current corridor capacity. The volume-to-capacity ratios are expressed as LOS grades for each primary rail corridor. Again, for legibility, rail corridors operating at LOS A, B, and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Figure 5.4 Future Corridor Volumes Compared to Current Corridor Capacity
2035 without Improvements



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Analysis of the 2035 levels of service, summarized in Table 5.1, shows that—without improvements—45 percent of primary corridor mileage will be operating below capacity (LOS A/B/C), 25 percent will be operating near or at capacity (LOS D/E), and 30 percent will be operating above capacity (LOS F). The resulting level of congestion would affect nearly every region of the country and would likely shut down the national rail network.

Table 5.1 Primary Rail Corridor Mileage by Future Level of Service Grade
2035 without Improvements

LOS Grade	Total Mileage	Percentage
A	4,895	9%
B	6,626	13%
C	11,708	23%
D	5,353	10%
E	7,980	15%
F	15,778	30%
Totals	52,340	100%

Source: Cambridge Systematics, Inc.

6.0 Rail Capacity Improvements

6.1 CAPACITY IMPROVEMENTS

Rail improvements were determined by comparing the current capacity in each primary corridor to the capacity needed to accommodate future train volumes. Capacities estimates were based on the capacities of typical rail corridor combinations of tracks, controls, and mix of train types as shown in Table 6.1. (This table was described in Section 4.0 and is repeated here for reference.)

Table 6.1 Average Capacities of Typical Rail-Freight Corridors
Trains per Day

		Trains per Day	
Number of Tracks	Type of Control	Practical Maximum If Multiple Train Types Use Corridor*	Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

The table presents average capacities for typical rail freight corridors. The actual capacities of the corridors were estimated using railroad-specific capacity tables. At the request of the railroads, these detailed capacity tables were not included in this report to protect confidential railroad business information.

Source: Class I railroad data aggregated by Cambridge Systematics, Inc.

For example, if a corridor with "one track and N/S-TWC control," which today accommodates 15 trains per day, must accommodate 35 trains per day in 2035, it is upgraded to "one track with CTC-TCS control," which accommodates 30 to 48 trains per day, depending on the mix of train types operating in the corridor.

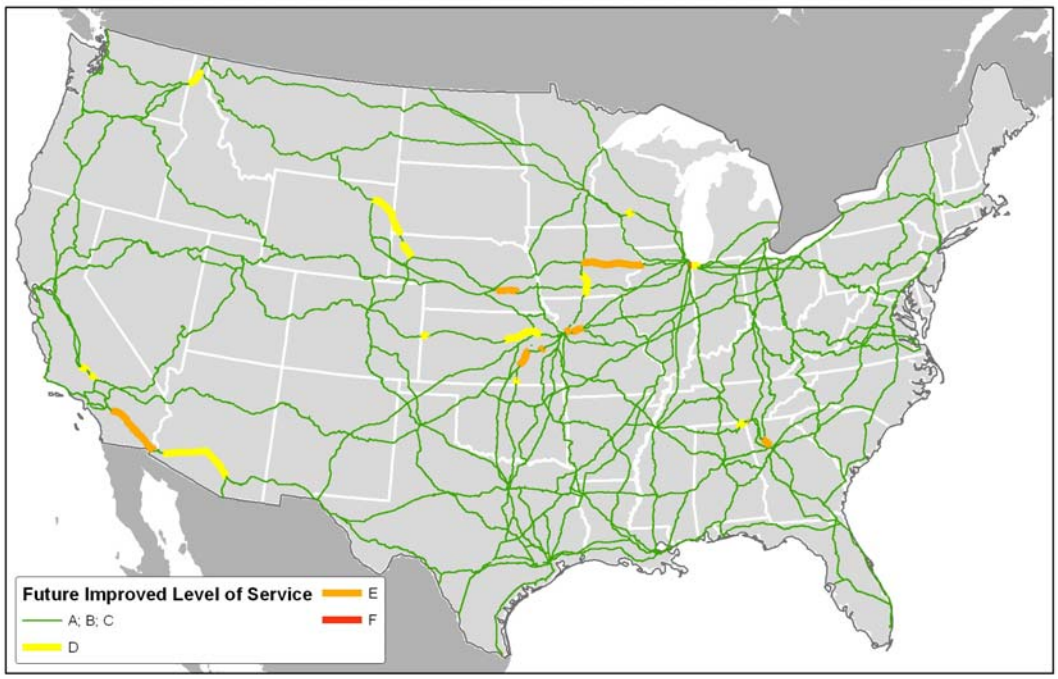
To avoid double-counting improvements that are currently programmed or underway, new improvements were selected to accommodate only forecast demand, not to correct current capacity shortfalls. If a corridor is at or above capacity today and needs additional capacity to accommodate future demand, improvements were programmed to bring the volume-to-capacity ratio back to the current ratio. For example, if the current volume-to-capacity ratio of a corridor is 0.85 and the future volume-to-capacity ratio without improvements is estimated to be 1.6, improvements were made to bring the volume-to-capacity ratio back to 0.85, not to 0.70. If a corridor is below capacity today and needs additional capacity to accommodate future demand, improvements were selected to bring the volume-to-capacity ratio up to a maximum of 0.70.

6.2 FUTURE VOLUMES COMPARED TO FUTURE CAPACITY

Figure 6.1 compares projected future corridor volumes in trains per day to projected future corridor capacity assuming that the necessary improvements are made. The volume-to-capacity ratios are expressed as LOS grades for each primary rail corridor. Again, rail corridors operating at LOS A, B and C (below practical capacity) have been mapped in green. Corridors operating at LOS D (near practical capacity) have been mapped in yellow, and corridors operating at LOS E (at practical capacity) have been mapped in orange. Rail corridors operating at LOS F (above capacity) have been mapped in red.

Analysis of the 2035 levels of service, summarized in Table 6.2, shows that—with improvements—97 percent of primary corridor mileage will be operating below capacity (LOS A/B/C), 2 percent will be near or at capacity (LOS D/E), and less than 1 percent will be operating above capacity (LOS F).

Figure 6.1 Future Train Volumes Compared to Future Train Capacity
2035 with Improvements



Source: Cambridge Systematics, Inc.

Note: Volumes are for the 85th percentile day.

Table 6.2 Primary Rail Corridor Mileage by Future Level of Service Grade
2035 with Improvements

LOS Grade	Total Mileage	Percentage
A	4,895	9%
B	15,198	29%
C	31,036	59%
D	608	1%
E	597	1%
F	6	<1%
Totals	52,340	100%

Source: Cambridge Systematics, Inc.

7.0 Investment Requirements

7.1 COST OF IMPROVEMENTS

The cost of improvements needed to accommodate rail freight demand in 2035 is estimated at $148 billion (in 2007 dollars). The Class I freight railroads' share of this cost is projected to be $135 billion; the short line and regional freight railroads' share is projected to be $13 billion. The cost estimates cover:

- Line expansion:
  - Upgrades to mainline tracks and signal control systems;
  - Improvements to significant rail bridges and tunnels;
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad tracks and bridges to accommodate 286,000-pound freight cars.
- Facility expansion:
  - Expansion of carload terminals, intermodal yards, and international gateway facilities owned by railroads; and
  - Expansion of Class I railroad service and support facilities such as fueling stations and maintenance facilities.

Table 7.1 summarizes the investments required by type of improvement for the Class I and the short line and regional railroads.

Table 7.1 Cost of Rail Freight Infrastructure Improvements
Millions of 2007 Dollars

	Class I Freight Railroads	Short Line and Regional Freight Railroads	Totals
Line Haul Expansion	$94,750	$320	$95,070
Major Bridges, Tunnels, and Clearance	$19,400	$5,000	$24,400
Branch Line Upgrades	$2,390	$7,230	$9,620
Intermodal Terminal Expansion	$9,320		$9,320
Carload Terminal Expansion	$6,620		$6,620
Service Facilities	$2,550		$2,550
Totals	$135,030	$12,550	$147,580

Source: Cambridge Systematics, Inc.

Notes: All estimates exclude real estate acquisition costs, consistent with national highway needs analysis study practices.

Line expansion costs for short line and regional railroads are only for segments used to connect the primary corridors, not the entire system.

The category Major Bridges, Tunnels, and Clearance covers very large projects such as expansion of major bridges and tunnels (or construction of new parallel bridges and tunnels) and corridor overhead clearance projects that are not adequately accounted for by per mile unit costs.

The category Branch Line Upgrades covers upgrades to secondary main and branch lines to meet 286,000-pound weight-limit standards for the Class I railroads. A preliminary analysis shows limited need to upgrade the capacity of secondary mainlines and branch lines.

Line expansion cost estimates were based on per mile construction costs to upgrade from one level of corridor capacity to another. Table 7.2 lists the average construction cost per mile for each set of upgrades. For example, upgrading a corridor from "one track and N/S-TWC control" to "one track with CTC-TCS control" would cost $700,000 per mile. All costs are reported in current (2007) dollars.

Table 7.2 Average Unit Costs

From		To		Construction Cost (per mile)
Tracks	Control	Tracks	Control	
1	N/S-TWC	1	CTC-TCS	$700,000
2	NS-TWC	2	CTC-TCS	$700,000
1	ABS	1	CTC-TCS	$500,000
2	ABS	2	CTC-TCS	$600,000
1	CTC-TCS	2	CTC-TCS	$3,800,000
2	CTC-TCS	3	CTC-TCS	$4,400,000
3	CTC-TCS	4	CTC-TCS	$4,400,000
4	CTC-TCS	5	CTC-TCS	$4,400,000
5	CTC-TCS	6	CTC-TCS	$4,400,000

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Note: The table presents average costs for typical rail freight corridors. The actual costs of the corridors were estimated using railroad-specific capacity tables. Per mile construction costs for Eastern rail corridors were higher than the averages presented in the table because of the number of urbanized areas, hilly terrain, and numerous river crossings. Conversely, per mile construction costs for Western rail corridors in non-urban areas were lower than the averages presented in the table because of the prevalence of flatter, non-urbanized areas along some Western railroad primary corridors. At the request of the railroads, the railroad-specific cost tables were not included in this report to protect confidential railroad business information.

Source: Cambridge Systematics based on Association of American Railroads and Class I railroads' data.

Expansion costs for major bridges and tunnels were estimated separately for each facility based on the cost of recent and comparable projects. Expansion costs for facilities such as intermodal yards, carload terminals, fueling stations, and maintenance facilities were estimated using the anticipated number of intermodal units, cars, and trains operating in the corridor.

The estimates do not include all line expansion costs on short line and regional railroads, nor the cost of expanding tunnels, bridges, and service facilities on the short lines and regionals. Neither the Class I nor the short line and regional railroad estimates include the cost of additional real estate, the cost to maintain or replace existing rail lines and facilities, or the cost to acquire additional locomotives and railcars.

Appendix A provides more information on the cost estimating methods.

7.2 COST SAVINGS FROM PRODUCTIVITY IMPROVEMENTS

The recommended improvements and the cost estimates assume that the future demand for rail freight transportation will be met by using current technology and existing rail corridors. The analysis also assumes that there will be no shift in freight traffic among modes (i.e., rail, truck, water), and no significant changes in regulation or other factors that could change the demand for or supply of rail freight services.

However, there are alternative futures that could, and eventually should, be examined. These include futures that assume significant changes in rail technology, major shifts in markets or trade patterns, and new innovations in railroad operations. A full examination of these alternative futures was not attempted for this first approximation study. However, a preliminary estimate was made of the potential cost savings from productivity improvements.

The railroads anticipate that they can improve train productivity by up to 0.5 percent per year over the 28-year period from 2007 to 2035. The productivity would be gained by carrying more freight over each primary rail corridor. This would be done by increasing the number of trains, hauling more cars per train, and loading railcars more efficiently to make better use of the 286,000-pound capacity of current railcars. These improvements would allow the railroads to carry the same amount of rail freight in 2035, but carry it with fewer trains.

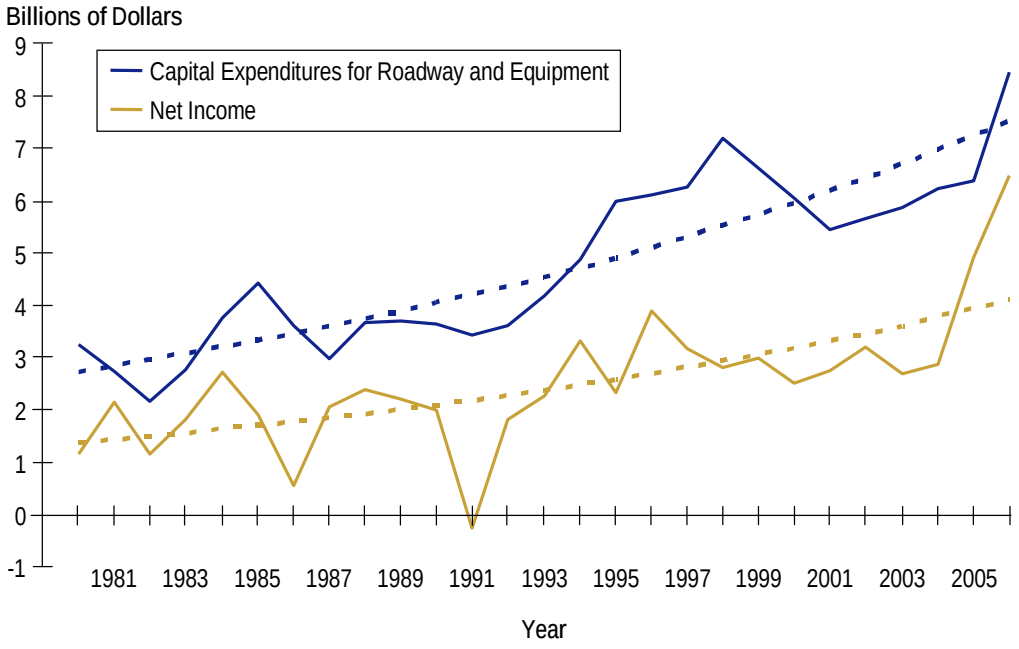
A 0.5 percent productivity improvement would reduce the number of trains to about 87 percent of the initial 2035 forecast number of trains. This would reduce capacity expansion needs in many corridors, reducing the cost of line expansion across all railroads from $148 billion to about $121 billion.[22] The Class I freight railroads' share for infrastructure expansion would be reduced from $135 billion to $109 billion, a savings of $26 billion. The short line and regional freight railroads' share of capital expenditures would be reduced from $12.6 billion to $12.3 billion, a savings of about $0.3 billion.

[22] Productivity improvements are only applied to line costs, not to terminals, yards, facilities, etc.

7.3 RAILROAD INVESTMENT CAPACITY

In general, Class I railroad capital expenditures have tracked income, as shown in Figure 7.1, increasing consistently (in current dollars) since the economic deregulation of the railroad industry in 1980. Class I capital expenditures for infrastructure expansion totaled $1.1 billion in 2005 and $1.4 billion in 2006. The AAR estimates that Class I capital expenditures for infrastructure expansion will total $1.9 billion in 2007.

Figure 7.1 Capital Investment and Income
Class I Railroads, 1981 to 2006, in Current Dollars



Source: American Association of Railroads data.

If rail revenues grow proportionally to rail tonnage, currently forecast to increase by 88 percent by 2035, and if the railroads maintain their current level of effort for expansion, then the Class I railroads will invest cumulatively about $70 billion over the 28-year period.

7.4 INVESTMENT REQUIREMENTS FOR CLASS I RAILROADS

The estimated cost of the improvements needed to accommodate rail freight demand in 2035 is $148 billion. Of this amount, the Class I freight railroads' share is projected to be $135 billion.

The Class I railroads anticipate that they will be able to generate approximately $96 billion of their $135 billion share through increased earnings from revenue growth, higher volumes, and productivity improvements, while continuing to renew existing infrastructure and equipment. If revenue and capital expenditures for expansion follow the growth in rail tonnage, as the railroads expect, the Class I railroads could realize about $70 billion of the $135 billion from growth. And if the Class I railroads can continue to achieve train productivity gains of up to 0.5 percent per year, the railroads could realize savings of $26 billion in reduced capital expenditures. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

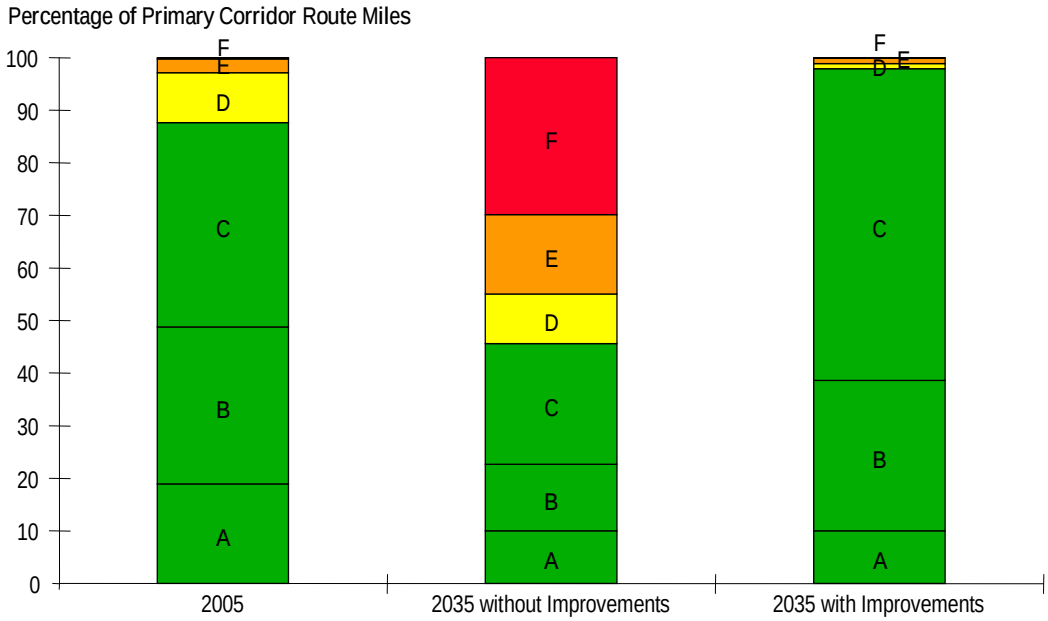
These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads may not be able to meet the U.S. DOT's forecast demand.

8.0 Conclusions

On first approximation, the investment in the continental U.S. rail network required to allow the freight railroads to meet the U.S. DOT's projected demand for rail freight transportation is $148 billion (in 2007 dollars). This level of investment would enable the freight railroads to keep pace with economic growth and meet the U.S. DOT's forecast demand for rail freight transportation in 2035.

The impact of the investment is illustrated in Figure 8.1, which compares the percentage of primary rail freight corridor miles by LOS grade and year.

Figure 8.1 Percentage of Rail-Freight Primary Corridor Route Miles by Level of Service Grade in 2005, 2035 without Capacity Improvements, and 2035 with Capacity Improvements



Source: Cambridge Systematics, Inc.

The left column shows the percentage of miles by LOS grade for the current rail system (2005 train volumes on the 85th percentile day compared to 2007 capacity). Red indicates the percentage of miles operating above capacity; yellow and orange the percentage of miles near or at capacity; and green, the percentage of miles below capacity. The center column shows the percentage of miles by LOS grade for the primary corridors in 2035 without improvements. Thirty percent of the rail miles in the primary corridors will be operating above capacity, causing severe congestion that will affect every region of the country and potentially shift freight to an already heavily congested highway system. Finally, the right column shows the estimated LOS grades in 2035 with improvements. The

improvements sharply reduce the number of primary corridor miles operating above capacity.

Meeting the U.S. DOT's forecast demand will require the Class I freight railroads to increase their investment in infrastructure expansion. The AAR estimates that between 2005 and 2007, Class I freight railroad capital expenditures for infrastructure expansion averaged $1.5 billion per year. To meet the U.S. DOT's forecast demand for 2035, the Class I freight railroads must invest $135 billion over the next 28 years or about $4.8 billion per year.

The Class I freight railroads anticipate that they will be able to meet most of this increase in investment through growth and productivity gains. If revenue and capital expenditures for expansion follow the growth in rail tonnage, the Class I railroads could realize about $70 billion of the $135 billion from growth. And if the Class I railroads can continue to achieve train productivity gains of up to 0.5 percent per year, the railroads could realize savings of $26 billion in reduced capital expenditures. This would leave a balance for the Class I freight railroads of $39 billion or about $1.4 billion per year to be funded from railroad investment tax incentives, public-private partnerships, or other sources.

These investment projections assume that the market will support rail freight prices sufficient to sustain long-term capital investments. If regulatory changes or unfunded legislative mandates reduce railroad earnings and productivity, investment and capacity expansion will be slower and the freight railroads may not be able to meet the U.S. DOT's forecast demand.

The findings of this study provide a starting point for assessing future rail freight capacity and investment requirements. The findings outline the improvements and investments required for the railroads to carry the freight tonnage forecast by the U.S. DOT. Additional work is needed to determine how much more capacity and investment would be needed for the railroads to increase their share of freight tonnage and reduce the rate of growth in truck traffic on highways. Finally, the forecasts and improvement estimates in this study do not fully anticipate future changes in markets, technology, regulation, and the business plans of shippers and carriers. Each could significantly reshape freight transportation demand, freight flow patterns, and railroad productivity, and, thus, rail freight infrastructure investment needs.

In summary, the findings point clearly to the need for more investment in rail freight infrastructure and a national strategy that supports rail capacity expansion and investment.

A. National Rail Freight Infrastructure Capacity and Investment Study: Methodology

A.1 INTRODUCTION

The objective of this study is to identify rail freight infrastructure improvements and investments in the continental U.S. rail network that will allow the freight railroads to meet the U.S. Department of Transportation's (DOT) projected demand for rail-freight transportation in 2035. This requires an understanding of the current and forecasted demand for rail services and the current and projected capacity of the rail network. The study encompasses the continental United States rail system.

The general approach was to divide the continental U.S. Class I railroad network into primary corridors; establish the volume of trains in 2005 and 2035; compare those volumes to current capacity; determine the additional capacity needed to accommodate 2035 volumes; identify the types of improvements warranted; and estimate the investment needed for these improvements. The improvements can be divided into line expansion and facility expansion, each with multiple components.

- Line expansion includes:
  - Upgrades to the Class I system mainlines control systems and/or number of tracks;
  - Improvements to significant bridges, tunnels, clearances, and other items above average costs;
  - Upgrades to Class I railroad secondary mainlines and branch lines to accommodate 286,000-pound freight cars; and
  - Upgrades to short line and regional railroad track and bridges to accommodate 286,000-pound freight cars.
- Facility expansion includes:
  - Expansion of capacity at Class I railroad-owned intermodal facilities, including terminals, ports and gateways;
  - Expansion of capacity at carload terminals (e.g., classification yards); and
  - Expansion of capacity at Class I railroad-owned service facilities (e.g., fueling stations, maintenance facilities).

A.2 LINE CAPACITY EXPANSION

The work steps to estimate the cost of expanding line capacity along primary Class I railroad corridors to meet U.S. DOT projected demand was as follows:

1. Divide the continental U.S. Class I railroad network into primary corridors;[23]
2. Establish the number of freight trains for a day representing the 85th percentile of the maximum trains per day from the 2005 Surface Transportation Board (STB) Carload Waybill Sample (Waybill);
3. Establish the number of scheduled passenger trains for a current average weekday, and combine with the freight trains;
4. Estimate the number of freight trains per day in 2035 by applying forecast rates from the Freight Analysis Framework Version 2.2 to the 2005 STB Waybill. Passenger train volumes were held constant;
5. Estimate the current capacity on the nation's primary rail corridors in trains per day based on current track configurations;
6. Compare the 2005 and 2035 freight and passenger trains per day to the current capacity, and identify the types of improvements necessary to maintain reliable rail service in 2035;
7. Estimate the construction costs of the improvement lines;
8. Estimate the cost of significant bridges, tunnels, clearance projects, etc.; and
9. Estimate the cost to upgrade all Class I branch lines and all short line and regional lines that are currently below 286,000-pound weight standards to the current standard.

Each of these is described in more detail in the following sections.

Divide the Continental U.S. Class I Railroad Network into Primary Corridors

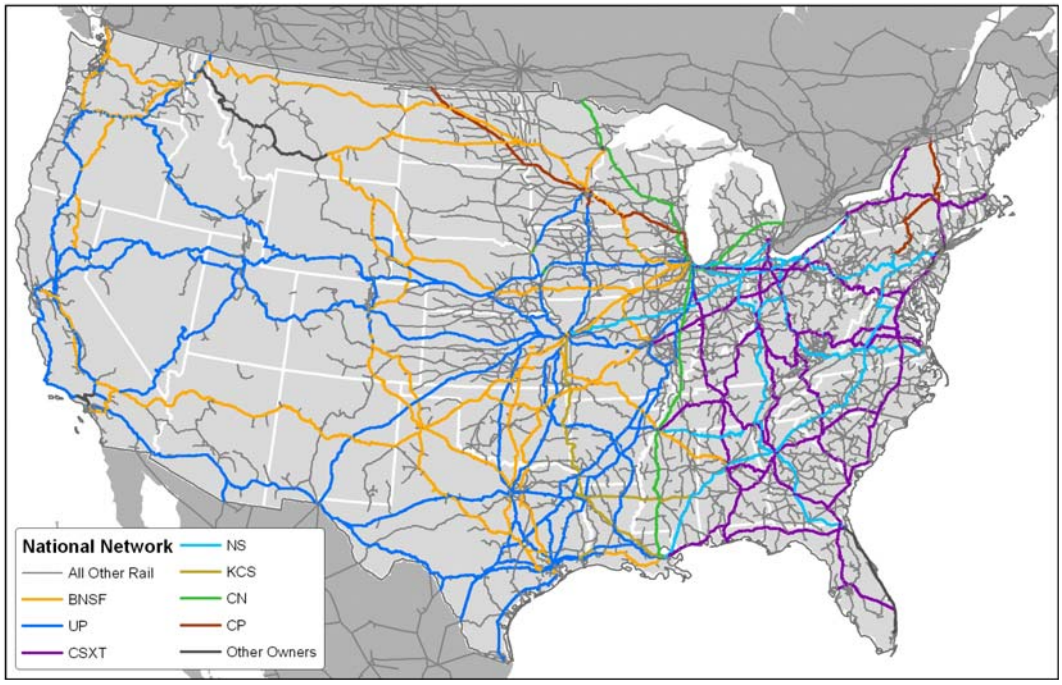
The initial work step was to divide the continental U.S. Class I railroad network into primary corridors. The corridors are mainline track and represent the lanes that haul the majority of the freight rail traffic. A corridor is roughly homogeneous with respect to traffic mix and type of infrastructure (i.e., number of tracks and control system).

[23] The Class I railroads covered in this study are BNSF, CN (U.S. operations), CP (U.S. operations), CSX, KCS, NS, and UP.

The beginnings and ends of the corridors are major urban areas corresponding with the U.S. Department of Transportation Freight Analysis Framework Version 2.2 ($FAF^{2.2}$) zones, major rail traffic generators such as the Powder River Basin coal fields, port complexes, and major rail traffic junctions.

Each of the Class I railroads participating in the study provided to Cambridge Systematics (CS) a map of their recommended primary corridors. CS aggregated this information into a national network of primary corridors for use in this study.

Figure A.1 National Rail Network and Primary Rail Corridors



Source: Cambridge Systematics, Inc.

The primary corridors were then mapped to a network combining the Oak Ridge National Laboratory (ORNL) Center for Transportation Analysis Rail Network Version 5-5 containing infrastructure attributes, with a network developed for the Tennessee Department of Transportation that assigns rail flows using minimum distance paths. In the course of this project the TDOT network was revised to include missing links with information from the ORNL network. The mapping was done in TransCAD, a commercially available transportation network modeling program.

Establish the Number of Freight Trains Operating on an 85th Percentile Day along Each Corridor in 2005

Data from the 2005 Surface Transportation Board Carload Waybill Sample was used to establish the total number of trains operating in each corridor with the following caveats:[24]

- Northbound Canadian traffic and southbound Mexican traffic will not be accounted for fully in this study because much of this traffic is absent from the Waybill Sample. Traffic terminating in Canada and Mexico (both U.S. originations and pass-through NAFTA traffic) often is waybilled to the U.S. border crossing, but much of the northbound Canadian traffic and southbound Mexican traffic is not reported.
- The Waybill Sample will not provide a complete picture of rail shipments end-to-end. The Waybill Sample is subject to "re-waybilling" (Rule 11 traffic) at key junctions such as Chicago. For example, one waybill may be written to cover a shipment from Los Angeles to Chicago, and a second waybill written to cover the same shipment as it moves on from Chicago to New York. This reporting practice makes it difficult to trace the entire route of some rail shipment. This issue did not affect the estimate of the number of trains operating in each corridor, and no effort was made to "link" these movements.

The Waybill Sample, which represents loaded revenue movements on the railroads, was adjusted to account for empty rail car moves. To estimate the empty car movements, empty return ratios were supplied by the AAR from the Uniform Rail Costing System (URCS), as shown in Table A.1. CS matched the empty return ratios to the Waybill data based on origin railroad, car type, and the car ownership flag. Table A.1 represents averaged empty return ratios for all cars ownerships – railroad, private, and leased. For a car ownership flag in the STB Waybill of "railroad" or "Trailer Train," specific ratios for railroad-owned cars were used. For a car ownership flag of "private," the privately owned car ratios were used. When the loaded car originated on a Class I carrier, the ratios for that carrier were applied. When a short line or regional railroad originated the load, the empty ratio was based on the East or West average, depending on whether the load originated east or west of the Mississippi River.

The carloads and intermodal units in the Waybill Sample were multiplied by the appropriate empty return ratio, reverse routed to represent the return movement from destination to origin, and then appended to the loaded cars in the Waybill. The assumption of reverse routing of the empties does not accurately reflect railroad operations, but it does place the correct amount of empty car miles on the network and it offers a reasonable approximation for this analysis.

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[24] The Waybill Sample is expanded to represent 100 percent of the movements on U.S. railroads.

Table A.1 Empty Return Ratios Used in the STB's URCS Phase 3 and Waybill Costing Programs
All Cars, 2005 Ratios

URCS CT Number	Car Type	BNSF	CN (U.S.)	CP (U.S.)	CSX	KCS	NS	UP	East	West
1	Box – 40-foot	1.33	1.72	1.75	1.59	1.52	1.72	1.38	1.65	1.38
2	Box – 50-foot	1.33	1.72	1.75	1.59	1.52	1.72	1.38	1.65	1.38
3	Box – Equipped	1.69	1.89	1.86	1.87	1.76	1.99	1.76	1.92	1.74
4	Gondola – Plain	1.96	1.86	2.31	1.94	1.97	1.91	2.36	1.92	2.26
5	Gondola – Equipped	1.85	2.11	1.98	1.83	2.00	1.89	1.89	1.86	1.88
6	Hopper – Covered	1.77	1.98	1.82	1.94	2.02	2.04	2.01	1.99	1.90
7	Hopper – Open Top General	1.94	1.92	2.14	1.95	1.94	1.96	2.09	1.95	2.05
8	Hopper – Open Top Special	1.96	2.03	2.11	1.95	2.00	2.01	2.13	1.98	2.09
9	Reefer – Mechanical	1.73	1.73	1.36	1.77	1.51	1.93	1.75	1.79	1.74
10	Reefer – Nonmechanical	1.58	2.35	1.88	1.93	5.42	1.81	1.86	1.90	1.72
11	Flat – Intermodal	1.15	1.18	1.10	1.15	1.05	1.09	1.15	1.12	1.15
12	Flat – Multilevel	1.27	1.45	1.38	1.54	1.19	1.59	1.45	1.55	1.41
13	Flat – General	2.41	2.47	2.24	1.79	1.94	2.66	201	2.29	2.16
14	Flat – Other	1.74	2.03	1.94	1.84	1.90	2.05	1.88	1.95	1.82
15	Tank < 22,000 Gallons	1.47	1.70	6.16	1.97	2.01	2.01	2.08	1.98	1.80
16	Tank >= 22,000 Gallons	1.54	1.88	2.30	2.01	2.06	2.03	2.04	2.02	1.83
17	All Other Freight Cars	1.34	1.70	2.56	1.94	2.04	1.52	2.03	1.69	1.59
18	Average Freight Car	1.51	1.85	1.59	1.75	1.83	1.70	1.82	1.74	1.69

Note: Empty Return Ratio defined as total miles divided by loaded miles. Ratios in spreadsheet are available to six significant digits – only three shown above. Ratios for 40-foot Box Cars use same value as 50-foot Box Car as a default. URCS Phase 3 and Waybill costing use ratios for All Other Freight Cars as defaults for railroad-owned tank cars.

Source: AAR, from the Uniform Rail Costing System.

Annual cars were then converted into average daily cars. This was done by first summarizing the Waybill Sample by waybill date and number of cars. The volume from the day representing the 85th percentile (based on volume of cars) was used to scale the annual volume to a daily volume. The 85th percentile threshold is consistent with highway capacity analysis methods.[25] This multiplier to convert annual cars and intermodal units in the Waybill Sample to an 85th percentile day was 0.00357. An 85th percentile day has 9.9 percent more cars than a 50th percentile day in the 2005 Waybill Sample.

The cars were subdivided into four service types – intermodal, bulk, general merchandise, and auto – the same four defined in the Waybill Sample. For each service type, the number of daily cars was converted into daily trains based on average train lengths supplied by BNSF, CSX, NS and UP. For the other railroads, CS estimated the train lengths. Table A.2 contains the average values used for eastern and western railroads. Intermodal unit train conversions were based on TOFC/COFC counts rather than cars. Adjustments were made in some corridors (e.g., Powder River Basin) to reflect actual operations of significantly longer trains.

Table A.2 Average Train Length
Number of Cars

Type of Service	Eastern Railroads	Western Railroads
Auto	57.0	63.9
Bulk	86.0	112.4
General Merchandise	82.0	80.7
Intermodal (TOFC/COFC count)	110.7	164.3

Source: Class I Railroad data averaged by Cambridge Systematics, Inc.

The next step was to unlink the trips. The Waybill Sample has records with a junction frequency up to six, indicating that seven railroads participated in the move (six junctions). The unlinked records break these apart so that each "trip" is only for a single railroad. The geographic endpoints of the trip can either be the origin and destination, or the junction location. These are generically referred to as the on-point and off-point. The Waybill does not have information on internal routings and classifications on an individual railroad.

The final step was to assign the train estimates to the ORNL rail network, using an all or nothing assignment in TransCAD. After combining the freight and

[25] This method of scaling the annual volume based on the 85th percentile is preferred over simply selecting the traffic on the day representing the 85th percentile. Scaling the annual volume will provide a more robust distribution of traffic over the rail lines that accounts for seasonality, instead of a snapshot of traffic for a single day.

passenger trains (see next section), density maps were developed and provided to BNSF, CSX, NS, and UP for review. The AAR reviewed the traffic density maps for CN, CP, and KCS. Corrections were made to the assignments and volumes when needed, and new maps were generated for further review.

As in all cases with this study, care was taken not to distribute confidential data about one railroad to the other railroads. Only the AAR and CS had access to the full information.

Establish the Current Number of Passenger Trains per Day

In addition to the total number of freight trains, the number of passenger trains operating on the network was determined. This includes estimates of Amtrak service, and commuter services such as the Virginia Railway Express and the Southeastern Pennsylvania Transportation Agency that make significant use of freight railroad lines. Not every commuter service was included, only those operating on the primary corridor network.

Most of the train information was obtained from available published schedules. Although the term "train" is used, it should more appropriately be called a "trip." A train that goes out and back was counted as two "trains." An average day was considered to be a weekday, not a weekend or holiday.

The passenger train estimates were assigned directly to the ORNL rail network using TransCAD, rather than applying a traffic assignment algorithm. Passenger train maps were generated and distributed to the study participants for review and comment.

The final step was to add the daily passenger train counts directly to the freight trains that had been assigned to the network.

Establish the Forecasted Number of Train Equivalents Operating Along Each Corridor for the Year 2035

The U.S. Department of Transportation's Freight Analysis Framework Version 2.2 ($FAF^{2.2}$) provides an estimate of all freight traffic moving in the U.S. by origin, destination, commodity, and mode. It has a 2002 base year and forecasts from 2010 to 2035 in five-year increments. The geography is based on 138 zones, with 114 zones in the U.S. It includes domestic traffic, North American traffic (Canada and Mexico border crossings, with the gateway location), and international traffic (by foreign region and U.S. zone, with an intermediate port). $FAF^{2.2}$ contains seven different modes of transportation: air and truck, other intermodal, pipeline and unknown, rail, truck, truck-rail, and water.

CS used the $FAF^{2.2}$ forecasts for 2035 for the rail and truck-rail modes by origin, destination, and commodity. The rail and truck-rail modes were combined into a single set of forecasts rates. The Waybill data was geographically matched to the $FAF^{2.2}$ zones by using a translation table mapping county to zone. Since the Waybill "starts" and "stops" trips at ports, the international forecasts were

included in the forecast rates based on the location of the port. For example, a move from Europe to the Atlanta zone with a port of Charleston, was considered a Charleston – Atlanta move and the forecasts rates were blended with the domestic forecast rates for other Charleston – Atlanta traffic by commodity. Rates by commodity for both Canadian and Mexican traffic were developed, and applied to Waybill data originating or terminating in those countries.

FAF$^{2.2}$ uses Standard Classification of Transported Goods (SCTG) codes. CS developed weighted averages of the forecast growth rates to establish growth factors for the general merchandise, intermodal, bulk and auto service types, based on the assignments in Table A.3. Weighted forecast growth rates for each service type were calculated for each FAF$^{2.2}$ origin-destination zone.

Table A.3 FAF$^{2.2}$ Commodity Assignment to Rail Service Type for Establishing Forecast Growth Rates

Auto	Bulk	Intermodal	Merchandise
• Motorized vehicles	• Animal feed • Cereal grains • Coal • Coal-n.e.c. • Metallic ores • Gravel • Nonmetallic minerals	• Alcoholic beverages • Electronics • Furniture • Machinery • Meat/seafood • Miscellaneous manufactured products • Mixed freight • Pharmaceuticals • Plastics/rubber • Precision instruments • Printed products • Textiles/leather • Tobacco products • Transport equipment	• Articles-base metal • Base metals • Basic chemicals • Building stone • Chemical products • Crude petroleum • Fertilizers • Fuel oils • Gasoline • Live animals/fish • Logs • Milled grain products • Natural sands • Nonmetal mineral products • Other agriculture products • Other foodstuffs • Unknown • Waste/scrap • Wood products • Newsprint/paper • Paper articles

The 2035 forecast growth rates were applied to the 2005 base-year loaded and empty cars by FAF$^{2.2}$ origin-destination zone and railroad service type. (The rates were adjusted to reflect the difference between the FAF$^{2.2}$ 2002 base year the Waybill 2005 survey year). This makes the assumption that empty return ratios will be the same in 2035 as they were in 2005. For empty cars, the forecast rate was based on the last commodity hauled. The forecast number of loaded and empty cars were converted into average trains per day, using the same conversion factors established for the 2005 data (i.e., average train lengths were held constant.)

The number of passenger trains was held at current levels. This study did not attempt to forecast 2035 passenger rail demand and service. A separate study is being conducted to develop passenger rail needs for presentation to the Commission.

The forecasted 2035 freight trains were then assigned to the ORNL rail network using an all or nothing assignment based on minimum distances, adjusted to reflect current rail road operating restrictions validated against existing volumes. Current passenger trains were added directly to the network to provide the complete 2035 year volumes. The results was mapped and sent to the railroads for review.

Estimate the Current Capacity for Each of the Primary Corridors

The capacity of the primary rail corridors was determined by defining a set of archetypical corridors, based on track and type of control, and then defining the capacity in terms of trains per day. Readily available information was supplied by the railroads participating in this study drawing from previously performed simulation studies. The information ranged from generic data to simulation results of specific corridors and general knowledge of operations.

CS used this information to identify a set of archetypical corridors that represented the various track and control combinations present along the corridors. The number of tracks was 1, 2, 3, or 4 and the type of controls included no signal or track warrant control (N/S-TWC), automated block signal (ABS), and centralized traffic control or train control system (CTC-TCS). To accommodate future demand, archetypical corridors of 5 and 6 tracks were added.

Comparison of the capacity information from each railroad yielded a range of values. One reason for this range was the mix of trains on the line. Lines with a nearly homogenous train mix have a higher capacity than lines with a mixture of train types. To adjust for this, each archetype was assigned a lower and an upper bound for the maximum number of trains. The lower bound was defined as the maximum number of trains per day, assuming an equal mix of merchandise-bulk, intermodal-auto, and passenger trains (one-third each). The upper bound was defined as the maximum number of trains per day, assuming 100 percent one type, and 0 percent of the other two types (complete homogeneity). To move between the lower bound and the upper bound, the standard deviation of the

train mix was used to scale the range between the bounds. For a train mix of 33 percent, 33 percent, and 33 percent for each of the three types, the standard deviation is zero; therefore a zero adjustment is added to the lower bound. A train mix of 100 percent, 0 percent, and 0 percent yields a standard deviation of 0.47, which was scaled to produce a factor that added to the lower bound equaled the upper bound.[26] A standard deviation falling between the minimum of zero and the maximum of 0.47 produced a capacity somewhere between the lower and upper bounds. Table A.4 contains the archetypes used in this study, along with the lower and upper capacity bounds.

Another reason for differences in capacity is due to differences in geography and topography. For similar types of track, a regions with longer runs and greater distances between urban areas can achieve higher speeds and greater throughput than areas with short runs and more closely spaced urban areas. Therefore, different capacity tables were developed based on regional variations. Table A.4 contains the average lower and upper maximum capacity bounds for the archetypes used in this study.

Rail capacity can take two forms. The "theoretical capacity" is the maximum number of trains assuming perfect conditions. The "practical capacity" considers factors such as possible disruptions, maintenance, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand. Practical capacity is about 70 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of C or D (described in the next section). At higher percentages, rail congestion increases and service reliability begins to deteriorate. The values established in Table A.4 represent practical capacity.

Using the number of tracks and the control system information from the ORNL rail network, CS developed a series of maps of track characteristics that were reviewed by the railroads. The track characteristics information was updated using feedback from the railroads, and then each of the primary rail corridors was assigned to one of the archetypes in Table A.4. Using the capacity for each archetype, and adjusting between the lower and upper bounds based on the standard deviation of the train mix, a practical capacity in trains per day was assigned to each of the primary corridors.

[26] The population standard deviation, not the sample standard deviation, was used since the three data points representing the percent mix of merchandise/bulk, intermodal/auto, and passenger encompasses the entire population.

Table A.4 Average Capacities of Archetypical Rail Corridors
Trains per Day

		Trains per Day	
Number of Tracks	Type of Control	Practical Maximum If Multiple Train Types Use Corridor*	Practical Maximum If Single Train Type Uses Corridor**
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Key: N/S-TWC – No Signal/Track Warrant Control.
ABS – Automatic Block Signaling.
CTC-TCS – Centralized Traffic Control/Traffic Control System.

Notes: * For example, a mix of merchandise, intermodal, and passenger trains.
** For example, all intermodal trains.

Source: Class I railroads' data aggregated by Cambridge Systematics, Inc.

Compare the 2005 and 2035 Train Volumes to the Current Capacity, and Identify the Types of Improvements Needed to Maintain Reliable Rail Service in 2035

Current corridor volumes were compared to current corridor capacity to assess congestion levels. This was done by calculating a volume-to-capacity ratio expressed as a level of service (LOS) grade. The LOS grades are listed in Table A.5. The LOS designations and descriptions correspond to the LOS designations used in highway system capacity and investment requirements studies.

Table A.5 Volume-to-Capacity Ratios and Level of Service (LOS) Grades

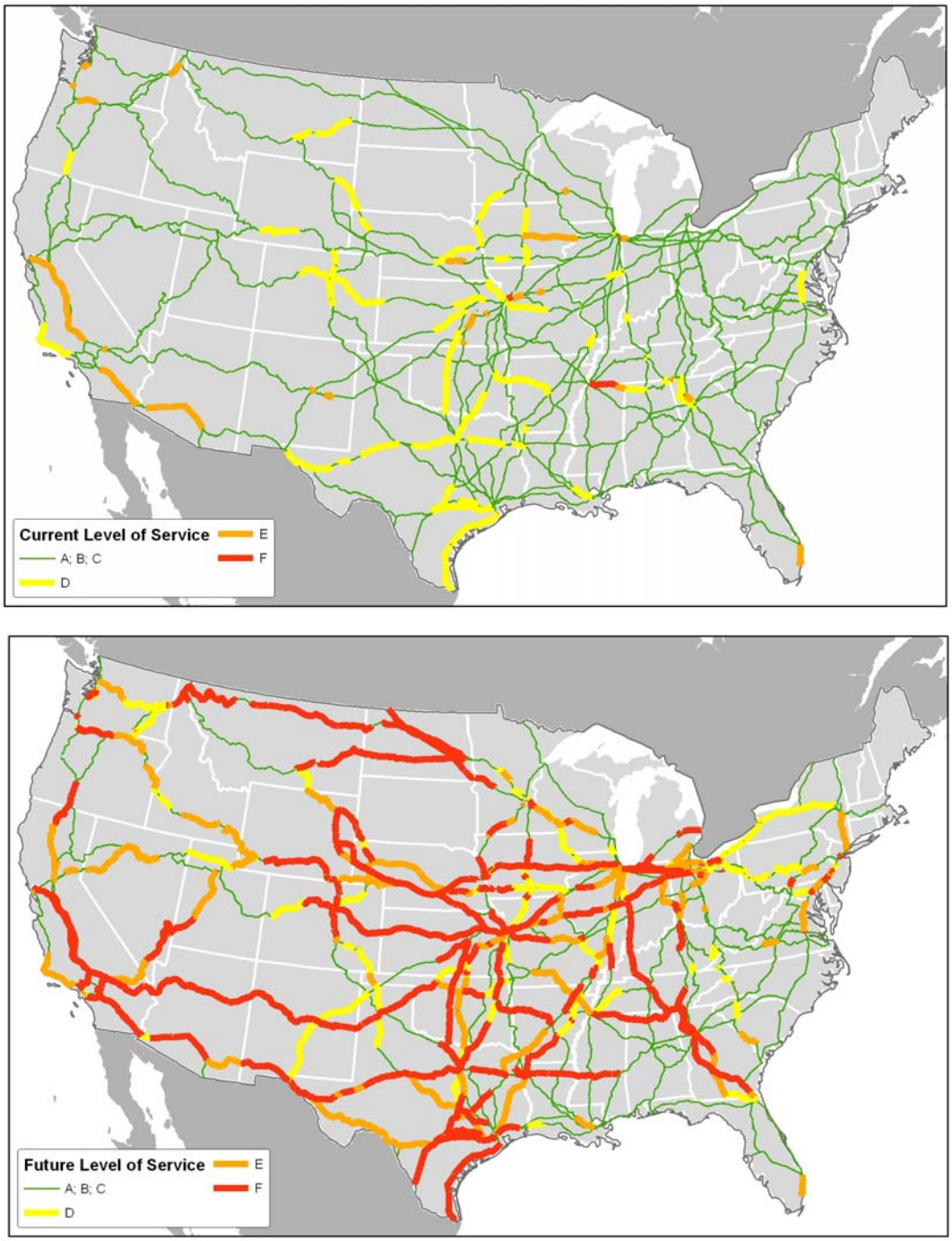
LOS Grade	Description		Volume/Capacity Ratio
A	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2
B			0.2 to 0.4
C			0.4 to 0.7
D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
E	At Capacity	Very heavy train flow with very limited capacity to accommo-date maintenance and recover from incidents	0.8 to 1.0
F	Above Capacity	Unstable flows; service break-down conditions	> 1.00

Source: Cambridge Systematics, Inc.

Rail corridors operating at LOS A, B or C are operating below capacity; they carry light to moderate train flows with sufficient unused capacity to accommodate maintenance work and recover quickly from incidents such weather delays, equipment failures, and minor accidents. Corridors operating at LOS D are operating near capacity; they carry heavy train flows with moderate capacity to accommodate maintenance and recover from incidents. Corridors operating at LOS E are operating at capacity; they carry very heavy train flows and have very limited capacity to accommodate maintenance and recover from incidents without substantial service delays. Corridors operating at LOS F are operating above capacity; train flows are unstable, and congestion and service delays are persistent and substantial. The LOS grades and descriptions correspond generally to the LOS grades used in highway system capacity and investment requirements studies.

Maps of the volume-to-capacity ratios, expressed as LOS classes, for the primary rail corridors are shown in Figure A.2. Rail corridors operating under capacity (at LOS A, B, or C) have been mapped in green, corridors operating near capacity (LOS D) have been mapped in yellow, rail corridors operating at capacity (LOS E) have been mapped in orange, and rail corridors operating over capacity (LOS F) have been mapped in red. Current volumes are those reported in the 2005 STB Waybill Sample (factored for empties and using an 85th percentile day). These volumes do not reflect fully recent trends, such as the increase in coal shipments moving from the Powder River Basin in Wyoming and Montana to Eastern utilities, nor the recent increase in intermodal containers delivered to East Coast marine ports and transferred to rail for inland delivery. Current capacity is the capacity as of 2007, and does not represent planned expansion.

Figure A.2 2005 and 2035 Train Volumes Compared to Current Train Capacity



Source: Cambridge Systematics, Inc.

Rail capacity line expansion improvements were estimated by identifying the upgrades to current capacity needed to accommodate future train volumes. To avoid double-counting improvements that are currently programmed or

underway, new improvements were selected to accommodate only forecast demand, not to correct current capacity shortfalls. If a corridor is below capacity today and needs additional capacity to accommodate future demand, improvements were selected to bring the volume-to-capacity ratio up to a maximum of 0.70. If a corridor is at or above capacity today and needs additional capacity to accommodate future demand, improvements were programmed to bring the volume-to-capacity ratio back to the current ratio. For example, if the current volume-to-capacity ratio of a corridor is 0.85 and the future volume-to-capacity ratio without improvements is estimated to be 1.6, improvements were made to bring the volume-to-capacity ratio back to 0.85, not to 0.70.

The hierarchy of corridor upgrades is shown in Table A.6. This hierarchy was used to expand from one archetypical corridor to another, until the capacity of the corridor could accommodate the forecasted 2035 volumes at a LOS of C or at current LOS if already operating at LOS D, E, or F. For example, if a corridor with "one track and N/S-TWC control" that today accommodates 16 to 20 trains per day needs to accommodate 35 trains per day in 2035, it would be upgraded to "one track with CTC-TCS control." As a rule, upgrades were selected to provide the appropriate level of service at the least cost. For the primary corridors under consideration, it was determined that any new construction would at a minimum involve a one-track CTC system (e.g., no expansion of lines operating on track warrants or with ABS on the primary corridors).

Table A.6 Hierarchy of Archetypical Rail-Freight Corridors
Practical Capacity in Trains per Day

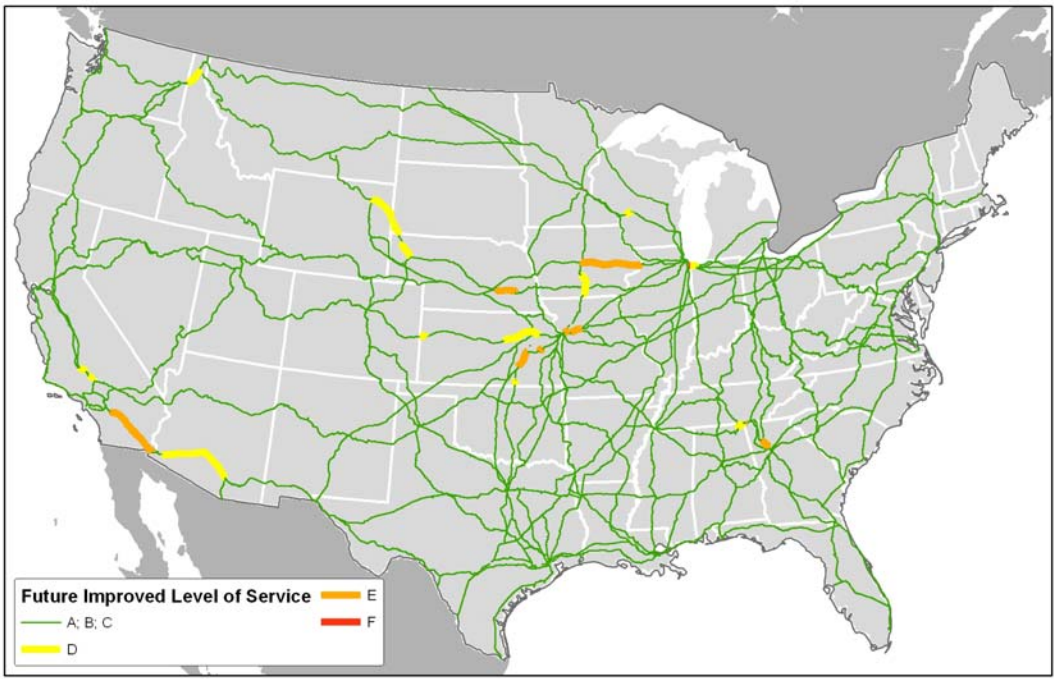
From				To			
Number of Tracks	Control	Lower Bound	Upper Bound	Number of Tracks	Control	Lower Bound	Upper Bound
1	NS-TWC	16	20	1	CTC-TCS	30	48
2	NS-TWC	28	35	2	CTC-TCS	75	100
1	ABS	18	25	1	CTC-TCS	30	48
2	ABS	53	80	2	CTC-TCS	75	100
1	CTC-TCS	30	48	2	CTC-TCS	75	100
2	CTC-TCS	75	100	3	CTC-TCS	133	163
3	CTC-TCS	133	163	4	CTC-TCS	173	230
4	CTC-TCS	173	230	5	CTC-TCS	248	340
5	CTC-TCS	248	340	6	CTC-TCS	360	415

Source: Class I railroads' data aggregated by Cambridge Systematics, Inc.

Note: N/S-TWC is No Signal and Track Warrant Control. ABS is Automatic Block Signaling. CTC-TCS is Centralized Traffic Control and Traffic Control System.

Figure A.3 compares future corridor volumes in trains per day to future corridor capacity assuming the necessary improvements are made. The volume-to-capacity ratios are expressed as LOS classes for each primary rail corridor. This map should look similar to the 2005 map in Figure A.2, since the goal was not to improve a corridor beyond the current level of service. This is not entirely possible due to the step-function nature of adding capacity. Adding an additional track can cause the LOS to drop several levels.

Figure A.3 Future Train Volumes Compared to Future Train Capacity
2035 with Improvements



Source: Cambridge Systematics, Inc.

Estimate the Construction Costs of the Improvement Lines

The costs to upgrade from one level of corridor capacity to another are listed in Table A.7. The costs are in unit costs per mile for construction. All costs are reported in current (2007) dollars. In the example cited above, upgrading a corridor from "one track and N/S-TWC control" to "one track with CTC-TCS control" would cost $700,000 per mile for construction. This is inclusive of design, engineering, and installation expenses. It is exclusive of any real estate costs.

Table A.7 presents average costs for typical rail freight corridors. The actual costs of the corridors were estimated using railroad-specific capacity tables. Per mile construction costs for Eastern rail corridors were about 25 percent higher than the averages presented in the table because of the number of urbanized areas, hilly terrain, and numerous river crossings. At the request of the railroads, the railroad-specific cost tables were not included in this report to protect confidential railroad business information.

Table A.7 Hierarchy of Archetypical Rail-Freight Corridors
Unit Cost to Upgrade Lines

From		To		Average Construction Cost Per Mile
Number of Tracks	Control	Number of Tracks	Control	
1	NS-TWC	1	CTC-TCS	$700,000
2	NS-TWC	2	CTC-TCS	$700,000
1	ABS	1	CTC-TCS	$500,000
2	ABS	2	CTC-TCS	$600,000
1	CTC-TCS	2	CTC-TCS	$3,800,000
2	CTC-TCS	3	CTC-TCS	$4,400,000
3	CTC-TCS	4	CTC-TCS	$4,400,000
4	CTC-TCS	5	CTC-TCS	$4,400,000
5	CTC-TCS	6	CTC-TCS	$4,400,000

Source: AAR and Class I railroads' data aggregated by Cambridge Systematics, Inc.

The costs in Table A.7 are additive. To expand from a one track CTC to a three track CTC would cost $8.2 million per mile ($3.8 million plus $4.4 million). The lower cost to go from one to two tracks (as opposed to 2 to 3 and 3 to 4) reflects cost savings from connecting existing sidings, less need to upgrade drainage, and other savings. The costs to maintain this additional track is not included in the total.

Estimate the Cost of Significant Bridges, Tunnels, Clearance Projects, etc.

Significant projects that are well outside the average unit cost in Table A.7, such as bridges spanning the Mississippi or Ohio River or expensive new or expanded tunnels and clearances, were included as additional costs in this study. The railroads, using maps provided by CS of where and how much capacity would be needed in 2035, individually provided estimates for significant structures.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. In most cases, the estimates were based on averages ranging from $200 to $300 million per structure. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A significant structures cost estimate was developed for CN, CP, and KCS by prorating the total significant structures cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Estimate the Cost to Upgrade Class I Branch Lines and Short Line and Regional Railroad Lines Currently Below 286,000-Pound Standards to Current Standards

The American Short Line and Regional Railroad Association (ASLRRA) released a report in 2000 that identified $6.9 billion in costs (1999 dollars) to upgrade the track of America's short line and regional railroads to accommodate the current standard weight of 286,000-pounds. This estimate was updated as part of this study. The update involved:

- The cost was inflated to represent 2007 dollars based on a construction price index developed from the U.S. Bureau of Labor statistics. This raised the cost from $6.9 billion to $10.8 billion.
- The cost of upgrading bridges was removed, and an ASLRRA provided estimate of $5 billion was included as a significant structures costs for short line and regional railroads.
- The AAR provided an estimate 898 route miles that has been upgraded between 2004 and 2007, an average of 299 miles per year. Using this ratio, an estimate of 2,395 miles were assumed to be upgraded to 286,000-pound standards between 1999 and 2007.
- The inflated cost to upgrade was reduced to reflect track already upgraded.

The final estimate for upgrading short line and regional railroad track to accommodate 286,000-pound loads is $7.2 billion (in 2007 dollars). The calculations are contained in Table A.8.

For the Class I railroad's branch lines, an average cost to upgrade was calculated at $300,000 per mile using the revised estimates from the ASLRRA. The miles of track not 286,000-pound ready was provided by BNSF, CSXT, NS, and UP. For CN, CP, and KCS, the estimated cost was prorated from the ratio of line expansion costs for those three railroads to the total line expansion costs.

Table A.8 Estimation of Cost to Upgrade Short Line and Regional Railroads to 286,000-Pound Weight Standard

Year	Inflation	Cost (Millions)	Cost Less Bridges (Millions)	Total Miles	Miles/Year Upgraded (2005 to 2007)	Estimated Miles Upgraded (1999 to 2007)	Assume 50 Percent Not 286,000-Ready (2007)	Estimated Percent Upgraded Since 1999	Estimated Cost to Upgrade (Millions)	Cost/Mile to Use for Class I (Millions)
1999	N/A	$6,861	$5,100	49,985	N/A	N/A	N/A	N/A	N/A	N/A
2007	0.575	$10,806	$8,033	48,194	299	2,395	24,097	9.94%	$7,234	$0.300

Source: 1999 Information from ASLRRA *An Estimation of the Investment in Track and Structures Needed to Handle 286,000-pound Rail Cars*.

Note: Assumption of 50 percent not 286,000 ready provided by AAR. Based on 22,256 miles (46 percent) not 286,000 ready in 2004 less 898 miles upgraded between 2004 and 2007. Exact percentage unavailable since 10 percent of track has unknown weight limit.

A.3 INTERMODAL AND CARLOAD TERMINALS, AND SERVICE FACILITY CAPACITY EXPANSION

The work steps to estimate the cost of expanding terminal and facility capacity necessary for the Class I railroads to meet U.S. DOT projected demand was as follows:

- Expansion of capacity at Class I railroad-owned intermodal facilities, including terminals, ports and gateways;
- Expansion of capacity at carload terminals; and
- Expansion of capacity at Class I railroad-owned service (e.g., fueling stations, maintenance facilities).

Expand Capacity at Class I Railroad-Owned Intermodal Facilities, Including Terminals, Ports and Gateways

The cost of expanding intermodal facilities, whether they are intermodal yards, railroad-owned port facilities, or international gateways, was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035. The railroads individually provided costs estimates for expanding the largest and most important intermodal facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

An intermodal facility cost estimate was developed for CN, CP, and KCS by pro-rating the total intermodal facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded intermodal facilities are not included.

Expand Capacity at Carload Terminals

The cost of expanding carload facilities (e.g., classification yards) was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035. The railroads individually provided costs estimates for expanding the largest and most important carload facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A carload facility cost estimate was developed for CN, CP, and KCS by prorating the total carload facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded carload facilities are not included.

Expand Capacity at Class I Railroad-Owned Service Facilities

The cost of expanding service facilities (e.g., fueling, car shops) was provided by the railroads. CS provided to each study participant a table of on-point and off-point volumes by county and railroad service type for 2005 and 2035, and a series of maps showing traffic volumes by corridor for 2035. The railroads individually provided costs estimates for expanding service facilities to accommodate the projected growth between 2005 and 2035. Consistent with other parts of this study, real estate costs were excluded.

It should be noted that these estimates are not based on detailed engineering studies, and therefore only provide a rough approximation. A detailed list of these projects is not contained in the report, since the cost estimates are average and should not be attributed to a specific project.

A service facility cost estimate was developed for CN, CP, and KCS by prorating the total service facility expansion cost by the ratio of the line haul expansion cost for these three railroads to the total line haul expansion cost.

Additional maintenance costs for these new and expanded service facilities are not included.