11

Railroad Terminals and Yards

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11.1 Defining Terminals and Yards

The railroad network in North America—or any other place—could not function without terminals and yards. When freight is moved, places must exist where it can be loaded and unloaded (terminals) and where railcars can be switched from one train to another (yards). Yards, which also serve as storage facilities, are owned and operated by the railroad itself (or in some cases, by a terminal railroad jointly owned by several larger, line-haul companies). Terminals are owned and operated by railroads, terminal companies, or independent third parties.

Terminals can take many forms. During the nineteenth century and part of the twentieth century, railroads hauled substantial quantities of less-than-carload freight (i.e., small shipments not large enough to fill an entire freight car); this required large warehouses at the terminals, where shipments could be cross docked,[1] and large terminal yards where freight cars could be marshaled. Today, however, railroads no longer carry less-than-carload freight, and those facilities have either disappeared or have been adapted for other uses. Types of terminals that may be found on modern railroads include the following;

- Bulk terminals—These are points where bulk commodities of various kinds are transferred from rail to other modes (such as ship or truck) or from other modes to rail. They can handle either dry cargo (coal, ore, grain) or bulk liquids (chemicals, petroleum products).

1 Cross docking is not a term used by railroads, but it is a now common term for less-than-truckload facilities.

- Intermodal terminals—Although bulk terminals are by definition intermodal transfer points, the term *intermodal terminal* generally applies to a terminal where ocean containers or truck trailers are moved between trucks (road haulage) and trains (rail). The term can also apply to facilities at ports, where ocean containers are moved to or from railcars.

- Bulk transload terminals—These are typically small yards where cars of bulk materials, such as plastic pellets or flour, are spotted on tracks that are readily accessible by truck so products can be transloaded from railcar to truck. These terminals are, in a way, an echo of the less-than-carload warehouses of an earlier time because they allow railroads to serve customers that do not have access to a rail siding by enabling small quantities of goods to be delivered directly to consignees by truck, while preserving some of the economies of rail haulage.

11.2 A Brief History of Railroad Yards and Terminals

The first railroads ran for short distances, typically from a traffic source (perhaps a coal mine or a quarry) to a single user, or a group of users, of the commodity, or to a rail-water transfer point. For example, early mine tramways in England often ran from a mine to a canal, and the first general service railroad in the world—the Stockton and Darlington in Yorkshire, England—carried mostly coal.

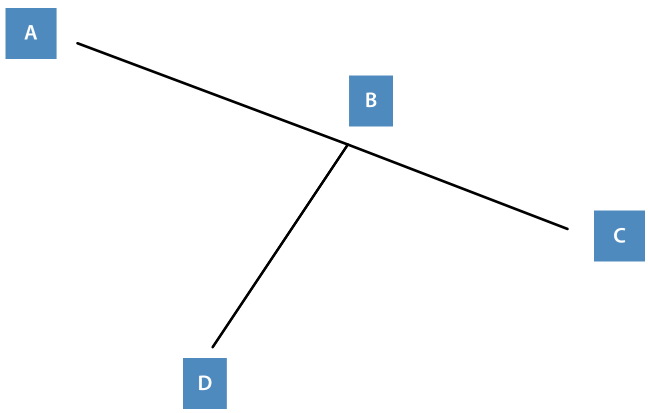
Such railroads used yards only to store wagons (as their freight and passenger vehicles were called) that were not immediately needed for service. In the simple topology of these early transportation systems, all trains operated from one end of the line to the other, carrying whatever traffic needed to be moved. As railroads grew from single lines into networks, operations inevitably became more complex.

Consider the simplified example in Figure 11-1. In this case, the railroad consists of two lines, the first from point A to point C via point B, and the second from B to D. There are yards at each point, and trains can run between any of the points. How would a railroad service this network?

The railroad would probably provide daily service between A and C and between B and D. Trains would be scheduled to connect at B, exchanging traffic with one another in the yard. If traffic between A and C grew to the point that it could justify an entire dedicated train, the railroad would begin operating a nonstop train between the two points. But since traffic to and from D would still need to be served, a through train from A to C, stopping at B to set out and receive traffic, would continue to operate in addition to the new nonstop train.

If traffic volume from A to D and from D to C continued to grow, the railroad might schedule nonstop trains between these points as well, but since B would

Figure 11-1 A two-line rail network



continue to be a traffic generator, a local train stopping at B would still be necessary. This illustrates a point: in general, train frequency in a rail network will remain at one train per day between each pair of traffic generators. If traffic grows, an additional through train to a more distant point will typically be added, rather than a second train between intermediate points. So while every shipper in this simple network has daily service, it will still be necessary for some traffic to connect from one train to another.

Connectivity is the problem. Imagine a shipper at A, sending traffic to D. Traffic is first taken to B, where it must wait in a yard for a connecting train to D. If this connection only runs once per day, a missed connection adds an additional 24 hours to transit time. This has important implications for intermodal freight, as will be seen later.

The simple example in Figure 11-1 assumes that all shippers can be served directly from the railroad at points A, B, C, and D. In the real world, not all shippers are located adjacent to railroad yards or have their own sidings where they can receive shipments. It was the efforts of railroads to serve those shippers that led to the development of intermodal rail service.

11.3 Types and Locations of Yards

Railroad yards come in three basic types:

- Classification yards (these are often hump yards, see below),
- Interchange yards, and
- Industry support yards.

Shippers using early railroads loaded their freight onto railcars, and those cars had to be moved across the rail network, sorted in yards at the junctions of rail lines, and often interchanged to other rail carriers for delivery to their final destination (whether shipper siding or team track).[2]

A typical rail shipment will move through at least three yards: an industry support yard near the location where the freight car was loaded on the shipper's siding, an intermediate classification yard, and an industry support yard near the final delivery location of the shipment. Typically, a local freight train or a switch engine would pull the car from an industry siding or a team track and deliver it to a local yard. The car would then be combined with others into a block of cars with similar destinations. This block would be forwarded on a through freight train to a classification yard, where it would be moved to another freight train for forwarding to the industry yard closest to the cars' destination. Alternatively, if the block contained cars with many different destinations, it might be broken apart and combined with other cars in the classification yard to form new blocks. Once sorted into a block for delivery to the local destination yard, the cars would be added to a through freight train destined for that yard, where a local freight or switch engine would then distribute the cars to shippers.

And this is a simple example! Analysis of rail movements of single-car shipments has shown that, in fact, the typical single-car shipment will move through no less than *five* yards—two industry support yards and three intermediate classification yards. (*1*) Clearly, the business of handling single-car shipments on a complex network can create some very interesting problems for industrial engineers. The following sections address the three basic types of railroad yards.

11.3.1. Classification Yards

Classification yards are typically the largest yards on rail networks, in terms of both acreage and the number and length of tracks. The function of classification yards is to receive trains of cars with many different destinations and to sort these trains, car by car, onto tracks corresponding to each destination (or to the next intermediate destination point, for cars destined for more distant points). Frequently, but not always, these class yards are hump yards, where much of the switching is accomplished by gravity. A train of cars to be classified is pushed up a hill (the "hump"), the cars are uncoupled one by one at the crest, and as they roll down into the classification bowl they are directed, via switches, to the proper track for their destination.

The first hump yards built by railroads were "rider humps." A brakeman would board each car as it was uncoupled at the crest of the hump and ride it down into the bowl, using the hand brake to regulate speed. The track switch-

2 Team tracks are public sidings where freight cars can be spotted, or positioned, for loading or unloading. They are so named because shippers could drive wagons pulled by teams of draft animals right up to the sidings to load or unload.

es that routed the car were controlled remotely from the hump tower, so the car would roll by gravity into the selected bowl track. Once the car was stopped on the appropriate track, the brakeman would return to the crest, either on foot or on a special trolley, to board another car.

Rider humps were dangerous and incurred high labor costs, but they were less expensive than flat switching, which involved using locomotives and crews to move freight cars from track to track. As early as the 1920s, railroads were looking for ways to reduce both the number of workers and the accident rate in rider hump yards. The first invention to be placed in service was the automatic retarder, a track-mounted device activated by hydraulics or compressed air that would squeeze the wheel flanges of the freight car against the rail; the resulting friction would slow the car down. (*2*) Early retarders were activated by operators in towers overlooking the hump, who used their eyes and experience to control the speed of the car. But as technology continued to improve, hump yards increasingly became automated.

The poor financial condition of the railroad industry after World War II meant that few rider humps survived into the 1970s. Railroads with capital to invest were finding ways to substitute technology for labor, and for those with money to invest, technology improved quickly in the post-war years. The use of radar devices to measure speed, for example, led to the automation of retarder operation.

A major innovation in the 1960s was the use of process control computers that received car waybill data (records of a freight car's destination and routing instructions) from the railroad's central computer. With this information, the local computer could provide instructions to the yardmaster on where each car should go once over the hump or could directly control switches and retarders so that the entire process—except for the uncoupling of cars at the crest of the hump—was automatic.[3]

In most modern hump yards, the switches that direct cars into specific tracks and the retarders that regulate the cars' speed are usually computer controlled. All freight cars in North America have been equipped since the early 1990s with radio frequency identification (RFID) tags, which are read by an interrogator as the cars are pushed over the hump; a computer then aligns the switches so that each car is sorted onto the correct track.

Figure 11-2 shows the layout of a typical hump yard—in this case, Rice Yard in Waycross, Georgia. Trains arrive in the receiving yard, and the railcars are then shoved over the hump crest by a switch engine. The cars are directed onto one of the 64 bowl tracks. When a bowl track is full, a trim engine pulls the cars through the throat of the yard and sets them on a track in the north or south

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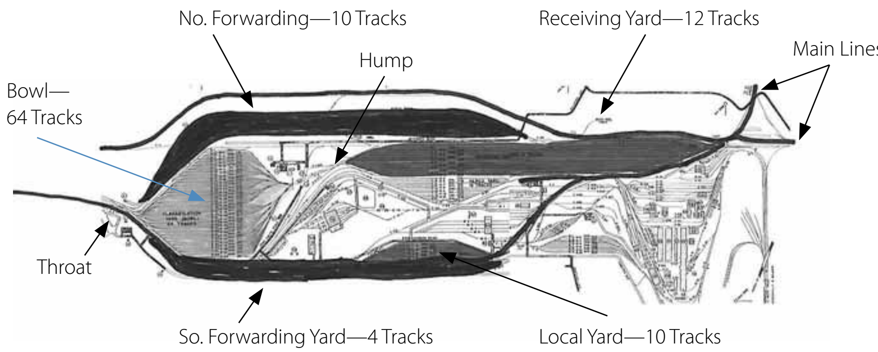
3 Because North American freight cars do not have fully automatic couplers, someone must manually pull the pin at the hump crest to allow one car to separate from the next.

Figure 11-2 Rice Yard, Waycross, Georgia



SOURCE: Carl Martland, "Factors Affecting Railroad Yard Performance," presentation at RASIG Roundtable, Pittsburgh, PA, Nov. 5, 2006.

forwarding yard, where they are combined into a train; locomotives are then added, and the train departs for its next destination.

Rice Yard is located in south Georgia, and trains arrive there from, and depart to, all points on the CSX network. To the south, trains run to and from terminal yards in Florida. To the north, trains run to other major classification yards in Atlanta, Rocky Mount, Louisville, Cincinnati, and Toledo, or to terminals or interchange points in New Orleans, Memphis, St. Louis, Chicago, Detroit, Baltimore, and other locations. CSX, like other Class I railroads, has multiple hump yards.[4]

The number of hump yards has been in decline for some years as railroad intermodal and unit train traffic (which typically does not pass through classification yards) has grown. In 1970 there were more than 140 hump yards on the North American rail network, but by 2000 this number had shrunk to less than 60. (*3*)

In the 1970s and 1980s, railroads devoted considerable effort to reducing transit time through yards and reducing the frequency of incorrect routes or missed connections in yards. These efforts largely failed to produce any overall improvement in service quality or a reduction in handling costs. Since the 1990s, therefore, railroads have sought to simplify their operating plans to reduce the numbers of yards through which freight cars must pass (and therefore reduce the total number of yards that must be operated and maintained). This has proven to be a more productive approach than trying to further improve yard operations.

Carload freight traffic remains a significant part of the traffic mix for all Class I railroads, accounting for between 40% and 60% of total revenues. (*4*)

4 Class I railroads must have at least $401.4 million in annual revenues (2008). According to the Association of American Railroads, the seven Class I railroads in North America operate 68% of the system mileage, employ 87% of the railroad workforce, and account for 93% of freight revenue.

Railroad traffic is growing, and therefore the number of hump yards will probably remain constant. Railroads continue to search for technological solutions that will reduce costs further, including remote control operation of switching locomotives; the labor portion of hump yard costs will thus likely decline. But large classification yards are likely to remain what they have always been—a necessary cost of doing business.

The number of hump yards on each of the Class I railroads is shown in Table 11-1.

Table 11-1 North American hump yards, 2003

Railroad	Number of Hump Yards
BNSF Railway	8
Canadian National	4
Canadian Pacific	5
CSX Transportation	13
Kansas City Southern Railway	1
Norfolk Southern Railway	7
Union Pacific Railroad	15
Terminal Companies*	6

Source: Cited reference *3*.

*Terminal railroads jointly owned by several Class I railroads. These include Conrail (CSX and Norfolk Southern), Indiana Harbor Belt (CSX and Canadian Pacific), Belt Railway of Chicago (CSX, Canadian Pacific, Norfolk Southern, and Union Pacific), and Terminal Railroad Association of St. Louis (Union Pacific, BNSF, CSX, and Norfolk Southern).

Major classification yards (not all of which are hump yards) perform a dual role for their owners. Most of the Class I yards are located at interior points on the network, where cars can be sorted to follow different routes to their final destinations or to interchange with other carriers. But some railroads also have yards at major interchange points, and the various terminal company hump yards are located at major interchanges (Chicago, St. Louis) or at points where large volumes of traffic originate or terminate (New York, Philadelphia).

Hump yards and major classification yards may also support local industries and serve as bases for local freight service, as well as for through freight trains.

11.3.2 Interchange Yards

The railroad industry must function as a single network, notwithstanding the fact that ownership is divided among seven large railroads and hundreds of smaller ones. This means that many shipments (in fact, a majority of all shipments) are handled by two or more carriers. At some point, then, traffic must be interchanged from one carrier to another.

Before 1981, when railroads were partially deregulated, the Interstate Commerce Commission often acted to preserve existing routings after railroad mergers and acquisitions by requiring gateways (points of interchange between railroads) to remain open. This preserved all premerger routing options. Since passage of the Staggers Act in 1980, many of these gateways and routing options have disappeared, as railroads have concentrated traffic on fewer routes and through fewer yards. But where traffic interchanges occur, there still must be yards to store the cars.

In some cases, the interchange yards are operated by neutral terminal companies. One example is the Belt Railway Company (BRC) of Chicago's Clearing Yard. The Class I owners of the Belt Railway operate through freight trains and transfer runs directly into the BRC yard, where they classify the traffic and deliver it to the appropriate railroads (or to local customers).

Most interchange yards, however, are just a few tracks on which one railroad can set out cars for pickup by another. Typically the yard is owned by one railroad, and another railroad has trackage rights to operate into the yard for pickup and delivery of traffic.

11.3.3 Industry Support Yards

These yards can be small or large, depending on the volume of traffic involved. They serve as originating points and terminals for through freight trains operating to and from classification yards, and also as bases for local freight trains that perform pickup and delivery at customer sidings. Typically one or more local freight trains will operate out of an industry support yard, and at least one through freight train per day will originate and terminate in, or set out (drop off) blocks of cars at, the yard. Most industry support yards are not hump yards, but there are exceptions. Oak Island Yard in Newark, New Jersey, is operated by "Little Conrail" (a terminal company established and jointly owned by CSX and Norfolk Southern to operate terminal trackage in areas where the two railroads did not have sufficient trackage or facilities to operate separately). Although Oak Island is a hump yard (and the only hump yard in the New York region), it classifies traffic only for local delivery or for pickup by Norfolk Southern and CSX through freight trains originating in the yard.

11.4 Intermodal Terminals

An intermodal freight terminal is a special kind of freight terminal, a place where two modes of transportation meet to interchange freight, either directly or through intermediate storage. For a freight terminal to be considered an intermodal terminal it must have the necessary space and equipment to receive cargo by one mode of transportation and ship it out by a different mode. In between the inbound and outbound movement, the cargo may be consolidated with other incoming cargo of the same type, separated into smaller outbound shipments, or directly transferred between two modes as part of a seamless intermodal shipment.

Railroad intermodal terminals come in several varieties. Most familiar are terminals where truck trailers or ocean containers, or both, are transferred from highway vehicles to railcars or vice versa. Less familiar, but equally important, are two other kinds of intermodal terminals. The first is a rail-water transfer terminal. Many of these exist on the rail network, and they take many forms and handle many commodities. They are located either at ports or along the inland waterway system of the United States, and they handle a variety of dry bulk commodities, as well as some liquids. Commodities handled may include aggregates (for concrete or other uses), coal, grains of various kinds, flour, iron ore and other metallic and nonmetallic ores, municipal solid waste, logs, and lumber.

Some of these commodities are also transferred from truck to rail, or the reverse. This is usually handled at smaller bulk terminals, where railcars are spotted on sidings, allowing the contents of a single railcar to be loaded onto multiple trucks; the empty railcar is then removed and replaced with another. Commodities handled at these rail-truck bulk terminals include road salt, flour, and plastic pellets of various kinds, as well as chemicals and other bulk liquids. These are modern versions of the team tracks, where railroads used to spot cars for shippers who lacked their own sidings. These terminals allow shippers to take advantage of low long-distance rail rates, but still receive commodities by truck, in truck-sized lots.

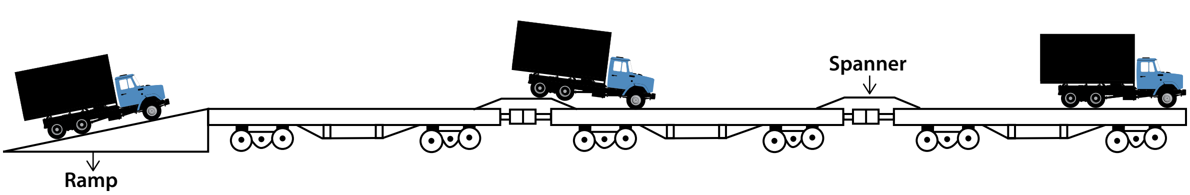
11.5 The Origins of Rail-Truck Intermodal Service

Even in the early days of railroads, not all shippers had their own siding; they relied on team tracks provided by the railroads. Shippers and consignees arrived with wagons and teams of horses or other draft animals (and later, trucks) to load or unload the cars. This system allowed shippers without direct rail access to move goods by rail.

Loading and unloading took time and effort, however. As early as the 1920s, some railroads began experimenting with the loading of truck trailers or entire trucks directly onto railroad flatcars. This became known as trailer-on-flatcar (TOFC) service. The easiest way to accomplish this was to build a ramp at the end of the siding and allow a vehicle to simply drive up the ramp and onto the deck of the flatcar. This was known as circus loading, because circus wagons were moved in this manner as early as the mid-nineteenth century. (Figure 11-3)

Circus loading was an attempt by railroads to simplify transportation by obviating the need to transfer cargo between truck and rail. It was attractive to the railroads because ramps were inexpensive, and the same trains that picked up freight cars from shipper sidings could place flatcars for loading and pick up the loaded flatcars. The problem, of course, was that service was slow due to the need to move these single-car shipments through multiple

➤ **Figure 11-3** Circus loading across multiple flatcars



SOURCE: *Cargo Specialists' Handbook* (FM 55-17), p. 20-3, figure 20-1. Washington, DC: Department of the Army, 1999.

yards and on connecting trains. The need for connections also introduced unreliability.

Consider an intermodal flatcar handled this way in regular train service. It must be picked up from the siding (probably by a switch engine or local freight train) and delivered to the nearest rail terminal, where it will be placed on a through freight train to be moved to the terminal nearest its destination (incurring at least a day's delay in the process). Upon arrival at the destination terminal, a switch engine or local freight train delivers the car to the local ramp (again perhaps incurring a day's delay). Assume that the probability of an on-time pickup and delivery is 90% at any point. Since the probabilities are all independent, they can be multiplied. In this three-stage example, with fairly good reliability at each stage, the overall end-to-end probability of on-time delivery is 72.9%. Put another way, this means that more than one shipment in four will fail to arrive as scheduled.

Shippers who used this intermodal rail service also had the option of simply having the goods transported directly from origin to destination by truck. With on-time performance as poor as in the above example and with roads steadily improving during the early twentieth century, many shippers did exactly that. It became apparent to railroads that to compete with the service offered by truckers, they would have to move intermodal traffic in dedicated trains. This would mean concentrating the traffic flows and reducing the number of locations at which intermodal traffic would be accepted for transport—a process analogous to the process through which railroads reduced the number of classification yards for carload freight. Reducing the number of points at which trailers were handled reduced costs, delays, and the possibility of misrouted shipments. It also increased service reliability.

11.5.1 The Transition to Lift-On, Lift-Off Technology

Railroads are characterized by economies of density. Many costs (for example, for train crews and track maintenance) do not increase linearly with increases in traffic. This means that each marginal unit of traffic carried may cost less than all those already moved. This provides railroads with an incentive to make intensive use of their tracks and terminals, running the longest and heaviest trains possible at frequent intervals—always, of course, assuming there is traffic to carry.

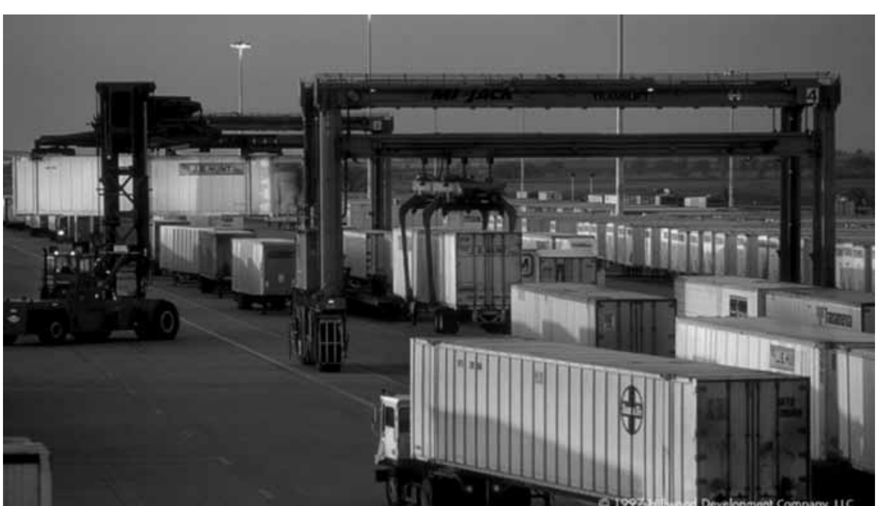
When railroads realized that a network of low-volume intermodal ramps could not produce competitive transit times at competitive prices, they began to develop a special-service network of dedicated intermodal trains. These trains would run only to and from purpose-designed intermodal terminals, and they would carry only intermodal traffic. By collecting larger volumes of traffic at a limited number of points, railroads could run solid intermodal trains on competitive and reliable schedules. In this way, railroads hoped to provide reliable service at reasonable cost.

The new, larger intermodal terminals were built with the idea of gathering enough traffic to load entire trains. To do this, an extensive drayage network needed to be developed, using short-haul drivers who bring trailers and containers from shippers to a centrally located intermodal terminal. Rather than being paid by the mile, as are most over-the-road drivers, these drivers are typically paid a flat rate per container or trailer (with longer drays usually being compensated at a higher rate).

The terminals themselves no longer use circus-type loading, although some in the rail intermodal industry still refer to intermodal terminals as ramps. Modern terminals rely on lift-on, lift-off loading methods, usually using either straddle cranes or piggy packers, which are specialized forklifts designed to load truck trailers and containers onto flatcars. When loading long trains, lift-on loading is much faster than circus loading, and it also enables "hot" loads to be retrieved from the middle of the train when necessary, whereas circus loading and unloading must occur sequentially. Figure 11-4 shows a typical intermodal terminal where truck trailers are primarily handled with lift-on, lift-off equipment.

The wrenching changes to the railroad industry during the Great Depression and World War II meant that large numbers of railroad facilities, particularly less-than-carload freight houses and yards, were rendered obsolete. Railroads were capital constrained and often wanted to take advantage of this available land to build intermodal terminals. The locations of those freight houses and yards were, however, not often optimal for intermodal terminals because they were in the old industrial centers of cities, with relatively poor access to express highways, and they were far from potential shippers. In addition, the sites were hemmed in by dense urban de-

➤ **Figure 11-4** BNSF Railway's Alliance Intermodal Facility, Fort Worth, Texas



velopment. But the land was free, so that is where the intermodal terminals were put.

Prior to the passage of the Staggers Rail Act in 1980 (which partially deregulated the railroads), railroads struggled to make intermodal rail traffic a success. Some in the industry believed that every truck trailer handled in TOFC service was traffic no longer moving in a boxcar—that railroads were cannibalizing their existing traffic to fill up intermodal trains. Nevertheless, the volume of intermodal traffic grew, and intermodal service was widely regarded as a success story at a time when the railroad industry was not experiencing much success.

The shift to lift-on, lift-off technology did have its disadvantages, however. First, trailers had to be specially modified with lifting points along the frame rails. These specially reinforced trailers were usually owned either by the railroads themselves or by large shippers. Small trucking lines and owner-operators thus could not use the new intermodal service, whereas they had been able to take advantage of circus-loaded service.

The new terminals were also more expensive to operate than local circus ramps, and they required drayage services to collect and distribute traffic. Typical costs for these activities today are about $30 per lift and $150 per dray movement, or a total of $360 for a typical movement involving two terminals and two dray movements. In the 1980s, the high fixed cost had led railroads to believe that rail intermodal could not compete with truck for distances of less than 750 miles. (*5*)

There was, however, a revolution underway even as early as the 1970s. Malcom McLean, a trucker, had started the first true intermodal service in 1955, using standard 35-foot containers that could move on the road or be loaded onto ships equipped with cell guides for stacking containers below deck. (*6*) (See Chapter 3.) It took some time for McLean's revolution to reach the railroad industry, but by the late 1970s it did.

11.5.2 The Container Revolution

Since the 1950s, various railroad industry commentators had been suggesting that it made little sense to take an entire truck trailer, wheels and all, and set it on a wheeled flatcar. "Why not just move the box?" they asked. The New York Central Railroad and several others did experiment with container service. New York Central called its version "Flexi-Van." Its advantage was that only the truck trailer was moved. Trailers were equipped with detachable wheel assemblies (bogies), and the flatcars were equipped with air-operated turntables so that a truck driver could back up to a railcar and load the trailer with no need for specialized lifting equipment. But the need for specialized railcars and trailers and the problems in managing a fleet of rubber-tired truck bogies (which sometimes had to travel in a gondola along with the truck trailers to ensure that sufficient bogies were available to unload the train), together with the fact that the industry was rapidly moving to lift-on, lift-off service, meant that Flexi-Van was only a historical footnote.

Much more successful was an idea originated by the Southern Pacific in the late 1970s, when one of its mechanical engineers conceived the idea of stacking two ocean containers on top of each other in a well car, which is a flatcar with a depressed section in the center, riding only 11 inches above the top of the rail. The double-stack car was an invention well suited to its time. The rail industry had already invested in lift-on, lift-off equipment for its terminals, and that equipment could also load double-stack cars. The double-stack car allowed twice as many containers to be carried on a train of a given length, meaning that tracks in intermodal terminals could be shorter, which saved money and time. Double-stack cars had a lower tare weight (weight of the empty car) than conventional flatcars. The lower weight yielded savings in the cost of the car and the cost of the fuel used to move the car, since more of the train's weight was due to lading (cargo carried). One study in the early 1990s found that use of double-stack cars reduced railroad direct movement costs by as much as 40%. (*7*)

What really drove railroads to move to containers was the growth in imports, especially from the Far East. McLean's innovation had been accepted worldwide, and this meant that more and more traffic entering the United States at West Coast ports was already in containers. Since the largest consumer markets were east of the Mississippi River, the traffic moved long distances to Midwest and East Coast markets. Railroads were especially well suited to compete for long-haul traffic, where the drayage cost was a relatively small part of the total movement costs. Containers could be stacked for storage, unlike truck trailers, which had to be parked in rows. Thus, a container terminal needed less land to store containers, and a double-stack train could use shorter terminal tracks. The result was a boom in railroad container transport beginning in the early 1980s and continuing into the twenty-first century.

11.5.3 Two Alternatives to Container Transportation

The container revolution was a great boon to railroads, bringing an enormous quantity of new traffic. However, the use of double-stack equipment and lift-on, lift-off technology limited the market available to railroads. Inventors and entrepreneurs continued to try to find ways to reduce terminal costs and reach a larger market by designing equipment that would not need expensive terminals or specially reinforced trailers. Two technologies are worth mentioning in this context.

The first is a type of highway truck trailer called a RoadRailer. The RoadRailer was first tested in the 1950s, but that version did not became popular with the railroads for a number of reasons. As originally conceived, the RoadRailer was a truck trailer with a railroad wheel set (two wheels plus an axle) attached behind the rubber-tired bogie under the rear of the trailer. This made the RoadRailer capable of running on both rails and highways. To move from highway to road, the trailer was backed onto a paved railroad track (which could be nothing more than gravel spread between the rails), and the trailer's air brake system was used to raise the highway wheels and lower the railroad bogie.

RoadRailers could be assembled into trains using special coupling mechanisms built into the trailers. An adapter car in front of the first trailer allowed a locomotive to couple up, and the entire train of trailers could be hauled over the railroad from terminal to terminal.

Advantages of the RoadRailer included its need for only very simple terminals (basically just a paved siding) and its lack of need for specialized railroad cars such as flatcars or double-stack cars. However, the disadvantages included a higher tare weight and a higher cost than conventional highway trailers, in part because of the need to carry a railroad wheel and axle set. Later designs for RoadRailers used fully detachable rail bogies, but this created other problems. As with the New York Central Flexi-Vans, railroads had to ensure there was an adequate supply of railroad bogies at each terminal to equip each RoadRailer train.

Today, however, RoadRailer service has become profitable in some markets. Norfolk Southern Corporation and Conrail formed a jointly owned subsidiary, Triple Crown Services, to operate RoadRailers on a network of routes covering both railroads in the early 1990s. Although Conrail no longer exists (its operations were split between Norfolk Southern and CSX in 1998), Triple Crown is still in business. Its routes now cover the eastern two-thirds of the United States, and it operates a fleet of 6,500 RoadRailers over tracks owned by Norfolk Southern and BNSF. (Figure 11-5)

A quite different concept is the Iron Highway, originally conceived by New York Air Brake and developed for CSX Intermodal (a unit of CSX Corporation). The Iron Highway is a continuous articulated platform that can carry standard, unreinforced truck trailers; the trailers are circus loaded, rather than lifted, onto the train. Today, the Iron Highway is used on Canadian Pacific's Expressway service between Montreal and Toronto. While operations differ somewhat from the original New York Air Brake concept, the Expressway service has been successful in attracting truck traffic that had not previously moved by rail in this corridor. (*8*) Two trains operate daily, and the service requires only a simple terminal. Trucking companies perform local pickup and delivery services; Canadian Pacific provides—and charges for—the line-haul service only.

Figure 11-5 RoadRailer trailer

Credit: Triple Crown Services

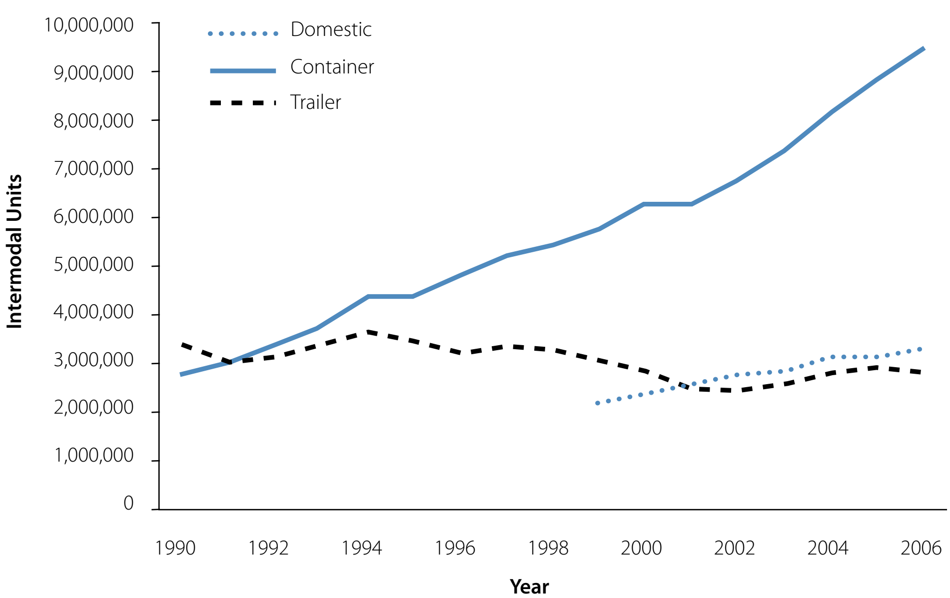
11.5.4 New Intermodal Terminals for a New Paradigm

The intermodal terminals built by railroads in the 1950s and 1960s for handling trailers were simply inadequate to handle the boom in container traffic. They were often poorly located for highway access, and they often lacked room to expand. Faced with steady and substantial growth in traffic (Figure 11-6), railroads had no choice but to build new greenfield terminals to keep up with demand. The new terminals could, of course, handle trailers as well as containers, but over the past two decades trailer volume has been in a slow decline.

The greenfield terminals offered railroads a chance to reduce costs and increase handling efficiency, since the new terminals were not limited to the footprint of an existing railroad yard. The new terminals have usually been positioned for convenient access to express highways, and they also incorporate land for additional functions such as warehousing and cross docking. In fact, “freight villages” are growing up around some terminals, such as the Union Pacific terminal at Rochelle, Illinois.

The reduction in costs made possible by improved terminals and by double-stack rail equipment has led to a rapid increase in the use of domestic containers. These are typically 53 feet long (the same as a modern truck trailer) and have a lighter tare weight than ocean containers, since they are designed to be stacked only two high on trains rather than six to nine high in the cell guides of container ships. As early as 2002, railroads were already moving more domestic containers than truck trailers.

➤ **Figure 11-6** Rail intermodal units handled (domestic containers are included in container total)



SOURCE: Association of American Railroads and Intermodal Association of North America

The rapid growth of domestic container traffic, the construction of new and more efficient terminals, and the partial deregulation of the railroad industry, combined with the rising cost of truck transportation, gave the railroads the pricing freedom to make intermodal traffic a contributor to the bottom line rather than just a source of incremental revenue (as TOFC traffic had often been during earlier years). In turn, this new profitability made it possible to fund the construction of new terminals at new locations, rather than simply reusing available land as had often been the case with TOFC terminals. These new terminals are typically in exurban locations, where land is cheap and where there is good access to express highways. Over the past decade, a number of new intermodal terminals have been constructed, including the following:

- Norfolk Southern in Austell, Georgia (west of Atlanta);
- Norfolk Southern in Bethlehem, Pennsylvania (New York region); and
- Union Pacific's Global III at Rochelle, Illinois (60 miles west of Chicago).

In each case, these terminals have been optimized for handling containers rather than trailers. Track lengths are sized for trains of double-stack equipment, now most commonly operated in articulated units with five wells each (Figure 11-7), which minimize tare weight and maximize the number of containers handled within a given train length.

Siting terminals in exurban locations provides sufficient room for containers to be stored on chassis, rather than on the ground. Not only is the equip-

➤ **Figure 11-7** Modern articulated double-stack equipment

Credit: Randolph Resor

ment needed to move on-chassis containers (dray tractors) less costly than that needed to move containers stored on the ground (straddle carriers), but the pickup of containers by local truckers is simpler—with containers stored on chassis, drivers can hook and haul, rather than having to wait for the container to be placed on a chassis.

Modern container terminals often also include an adjacent yard for carload freight, as well as servicing facilities for locomotives. Figure 11-8 shows the BNSF Railway's Alliance Intermodal Facility in Fort Worth, Texas. On the right side of the photo is the intermodal terminal, with a trailer parking area visible at the extreme right. To the left is a yard for mixed freight shipments. Not visible in this photo is a nearby industrial park, where warehouses receive carload freight service out of the mixed freight yard.

The Alliance Intermodal Facility was developed by a third party, Hillwood Development Company LLC, for BNSF, and the facility is operated by a contractor. This is typical for modern intermodal terminals, as contractors can often achieve lower costs through less restrictive work rules and lower labor rates.

11.5.5 Port Intermodal Terminals

The container revolution came about in part because of McLean's vision of freight containerization. But McLean's vision did not originally include rail-truck transfer—he was interested in transferring containers between trucks and ocean carriers.

➤ **Figure 11-8** BNSF Railway's Alliance Intermodal Facility, Fort Worth, Texas

It was ocean traffic that led railroads to consider double-stack equipment, and ocean traffic that generated the surge in inland container movement. McLean's 35-foot boxes were quickly supplanted by standard 20-foot and 40-foot boxes, typically eight feet wide by eight feet high, for international trade. High-cube boxes with a nine-foot, six-inch height also exist, and it is this that drives the 23-foot clearance requirement for railroad double-stack equipment (one foot of clearance between the top of rail and the bottom of the car, plus 19 feet for the two containers, plus a six-inch allowance for interbox connectors that hold the containers together, plus two feet six inches to allow for spring compression, bounce, and sway).

Just as lift-on, lift-off rail intermodal terminals looked very different than the circus-style ramps used in the early days of rail container movement, modern container ports look quite different from the finger piers and transit sheds of an earlier era.

While the phrase *on-dock rail* is common, that does not often mean that a rail line runs right along the dock edge. Rather, it means a rail terminal is located within the perimeter of the port, so that containers do not have to move over public streets as they are transported from ship to train. This reduces costs, since movement within the port is normally included in port stevedoring charges and is usually less costly, on a per-box basis, than even a short dray over public streets.

A modern container port, the Port of Los Angeles, is shown in Figure 11-9. Container cranes are to the left of the photo (one is shown working a ship at the dock). Containers are stored on the ground to the right of the cranes. The railroad container yard is in the right foreground. This is a good example of on-dock rail.

While ports originally hoped that on-dock rail would reduce the volume of containers moving on public streets, continual improvements in cargo-handling technology have made the replacement of dray movements a difficult task. For example, domestic truck trailers in the United States are now mostly 53 feet long and nine feet six inches high, as are domestic containers. These trucks and containers are also eight feet six inches wide, meaning that a domestic truck trailer or container has nearly 4,280 cubic feet of interior space. By contrast, a standard 40-foot container has only 2,560 cubic feet of interior space. This 67% volume advantage is sufficiently compelling that many inbound boxes from Asia are now drayed from West Coast ports to local warehouses, where they are emptied and the goods transferred to truck trailers or 53-foot domestic containers. In many cases, these trailers or containers are then taken to railroad intermodal facilities.

In an attempt to reduce highway traffic, the ports of Los Angeles and Long Beach, several cities in the Los Angeles basin, and the state of California formed the Alameda Corridor Transportation Authority (ACTA) to build a new rail route from downtown Los Angeles to the ports, removing trains from slow and

Figure 11-9 Port of Los Angeles

Credit: Los Angeles County Department of Public Works

roundabout routes and eliminating many at-grade highway crossings. This was a pioneering example of a public-private partnership. Funding was provided by the state of California, the federal government, and the ports, as well as by bonds sold to finance a portion of the construction cost. The corridor is maintained and operated by ACTA and is paid for by a $40 charge on every container moving from the ports to the main rail facilities near downtown of Los Angeles.

It was originally hoped that solid trains of ISO containers would move directly from ship side to points in the eastern United States. However, there is less of this traffic than originally forecast due to the increasing use of domestic 53-foot containers. But as new container ships with cell guides for 53-foot containers come on line, this should become less of a problem.

11.6 Other Types of Intermodal Terminals

Bulk commodity movements are extremely important to the rail industry (46% of railcar loadings are coal), and much of this traffic moves on more than one mode of transportation.

These terminals vary greatly in size, but their basic construction is similar. They typically include a railroad yard to store inbound and outbound cars; material handling equipment to move the product between freight cars, storage locations, and trucks, barges, or ships; and a scale to weigh cars before they are unloaded or after they are loaded. Because of the variety of materials and the volumes handled, design details vary; terminals range from small rail-truck bulk transfer terminals to large rail-water coal and ore terminals.

For example, ore docks, as are commonly found on Lake Superior, allow small railroad cars, called ore jennies, to be pushed on tracks laid across the top of the docks. Each car stops above an ore pocket, and the car's bottom dump gate is opened to discharge the car's contents into the pocket. A chute attached to each pocket directs the contents into the hold of an ore boat. Each pocket holds considerably more ore than one ore jenny can carry, so multiple trains are needed to fill each pocket, but when the pockets are full they can fill an entire ore boat.

On a wholly different scale are the many small bulk terminals at which rail customers can transfer products (either dry or liquid bulk) from railcars to trucks.

11.7 The Future of Rail Terminals and Yards

Railroading in the twenty-first century is undergoing a profound transformation that began with deregulation. Railroad traffic has grown enormously since then, confounding the popular perception of railroads as an industry of the past. However, the railroad industry of the twenty-first century is greatly changed from even 30 years ago.

For one thing, gross ton-miles have more than doubled since 1981, and the growth in some categories of traffic (notably intermodal) has been even faster. However, carload traffic has been growing more slowly, and in some market areas has even been declining. This scenario, along with efforts by railroads to reduce the cost and increase the reliability of carload freight shipments, has led to the closure of many large classification yards. Neither intermodal trains nor unit trains of bulk commodities are classified in yards. As carload traffic becomes a smaller part of total rail traffic, the facilities dedicated to handling carload traffic have grown smaller as well, although the growth in traffic has meant that yard closures have occurred more slowly than previously expected.

By contrast, new intermodal terminals are being constructed in a number of locations across the United States and Canada by all seven Class I railroads. These terminals can handle containers at lower cost and with more efficiency than the terminals they replace. They also frequently serve as the centers of freight villages, with clusters of storage and cross-docking warehouses surrounding the rail yard.

West Coast ports have been adding intermodal capacity as well, and in some cases they have added new track (the Alameda Corridor is one example) and new road access to handle the growth in intermodal traffic.

These trends appear likely to continue. While there is a movement toward bringing Asian cargo directly to the US East Coast (either through the Panama Canal or through the Suez Canal), high prices for fuel, increasing highway congestion, and a growing truck driver shortage should continue to spur growth of rail intermodal traffic. It is likely that more intermodal terminals will be constructed in the near and medium term.

There are signs that even carload traffic may rebound, at least in a few markets. A modern refrigerated boxcar has more than three times the volume of a refrigerated container or truck trailer, so shippers of less perishable agricultural goods (onions, apples) have begun to return to boxcars. This is traffic that moved from rail carload freight service to truck more than 30 years ago, and still does not move in carload freight service today. Rather, it moves in dedicated trains such as BNSF's Ice Cold Express, a high-priority solid train of refrigerated containers that runs from California to the New York region.

So while the sheer growth of all railroad traffic may keep the remaining hump yards busy, the trend seems clear. The railroad industry of the twenty-first century will likely be a series of special service networks, made up of dedicated trains carrying high-value commodities to and from specialized rail terminals.

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MAX. GROSS WEIGHT
3175 KGS.
TARE WEIGHT 172 KGS.

12

Warehousing and Distribution Centers

Bruce X. Wang and Teresa Adams

12.1 Introduction

Warehousing and distribution operations date back to the emergence of manufacturing and transportation. Warehouses primarily serve as storage points along the supply chain, but they can also serve to provide value-added services such as labeling and repackaging. Distribution centers are special forms of warehouses that focus on throughput—i.e., products from various manufacturers are combined into shipments of precise quantities for distribution according to customer needs.

Before the mid-twentieth century, warehouses and distribution centers were largely isolated from other upstream or downstream activities in the supply chain. Today, they are integral parts of the supply chain. From the 1950s to the 1990s, research on inventory management led to new inventory strategies that were able to respond quickly to changes in demand and market characteristics. Cost reduction strategies targeted warehouses and distribution centers because excess inventory contributes to product waste and revenue losses. Yet, inventory shortages can lead to lost revenue opportunities. Ordering policies were thus implemented to define when and how much to order in relation to market characteristics and freight system performance.

Since the 1990s, dramatic developments have occurred in supply chain integration and in the use of warehouses and distribution centers as nodes in the distribution network. *(1)* Individual facility performance is important, but how facilities function collaboratively, where to locate them, and how to operate them for the most efficient outcome of the supply chain are also critical factors. Information technologies and computer networks enable manufacturers, distributors, and retailers to share information. Managers and planners achieve better knowledge of markets and the production and distribution performances. The growth in available data about the freight system performance, warehousing operational efficiency, product pricing, and demand, coupled with the application of operations research theories, has led to production, distribution, and retail pricing that is more and more integrated.

Information technology has played, and will continue to play, a key role in the development of operational strategies for warehouses and distribution centers and supply chain integration. The traditional pattern of the wholesaler, the retailer, and the consumer is being challenged. Extensive use of the Internet for online business, new marketing channels, and the growth of business-to-business relationships have been the drivers for new distribution practices. Large distribution centers have been established for direct sales (largely through express courier services), such as those for Amazon.com. Information sharing through computer networks and the Internet expedites the forging of supply chain partnerships. New enterprise resource planning systems integrate suppliers and vendors through inventory management. Tremendous growth in computational capacity has enabled implementation of operations research theories for large-scale optimizations, often in real time. The development of global positioning systems (GPS), geographic information systems (GIS), radio frequency identification (RFID), and other sensor and detection technologies, coupled with the use of the Internet, makes product tracking a reality, which in turn enables control of product flow and inventory changes over the entire distribution and production system.

In today's world, warehouses and distribution centers are integrated into the supply chain on a global scale. Many global companies strategically locate and then relocate their major production and distribution centers to take advantage of changing global resources, labor, and other factors.

In this chapter, we discuss key functions and considerations for a distribution network of warehouses and distribution centers in achieving the supply chain goal to reduce costs by increasing the system operational efficiency and reliability. Inventory management is a key function for both warehouses and distribution centers. Inventory is money, and holding any input or product idle is to be avoided. The task is to minimize holding while maintaining a stable supply chain with acceptable risk to both the suppliers and retailers.

One can view the network of warehouses and distribution centers from different perspectives. From a transportation perspective, the number of warehouses and their location involves a trade-off between transport costs to market and scale economies of warehouse and distribution operations. From the perspective of supply chain integration, warehouses and distribution centers are related to the supply chain by the positioning of warehouses in a serial system in which each vendor is also a supplier to its next customer. The chapter ends with a brief discussion of contemporary trends and challenges that are impacting supply chain operations.

12.2 Warehousing and Distribution Centers

Warehousing refers to the operations within a facility for the purpose of storage. Many important decisions are associated with warehousing operations. When to order for replenishment and how much to order are two of the most important. Another decision is how to allocate warehouse space to different items—each product occupying a fixed space versus continual space reallocation when inventory changes, or more shelf space versus more aisle space. In this section, warehousing operations and the related decisions that govern their individual functions are introduced.

12.2.1 Warehouse Function and Types

A warehouse has roofed spaces, shelves, lifting equipment, loading dock, and management offices. Products are often packaged in pallets and lifted onto racks to utilize vertical space. A number of trade-offs in warehouse design influence its operations. For example, designers have to balance between build out (horizontal) and build up (vertical), and between two-dock (at both sides of the warehouse) and single-dock layouts.

Warehousing operations perform the important role of rearranging the quantities and assortment of products as they move through the supply chain. Briefly, there are four major functions of warehousing operations:

1) Accumulating: collecting together a quantity of stock, also referred to as bulk making;
2) Break bulking: breaking large quantities into smaller ones, possibly to meet individual customer needs;
3) Assorting: building up a variety of different products to satisfy demand; and
4) Sorting: separating products into grades and quantities desired by different target markets. *(2)*

A more recent warehouse function is that of value-added activities, which refers to labeling, (re)packaging, and other activities that might otherwise be

Figure 12-1 Warehouse physical design

done by a manufacturer. These value-added activities give flexibility to the distributor to satisfy particular customers.

Research and development in supply chain management over the past decades has made warehousing operations more efficient and increasingly sophisticated. In contrast to early warehousing, contemporary warehousing operations make use of automation. An excellent example is the use of stock-to-picker system, in which ordered parts are delivered by conveyor belt or other means directly to a location where the picker assembles them into packages for distribution. In contrast, a picker-to-stock system requires the order pickers to retrieve each individual ordered item from stock. In addition, computerized systems now enable automatic updates of inventory levels to meet future demand and automatic calculation of best ordering policies. Automatic tracking of the thousands of items in stock makes it possible to automatically place orders for inventory replenishment.

There are three categories of warehousing: public, private, and contract.

Public Warehousing

Public warehouses are similar to the concept of for-hire carriers in transportation. Public warehouses provide expertise in personnel management and regulatory knowledge. They often provide break bulking and repackaging services. Users contract with the public warehouse for a certain amount of space and certain types of services for an agreed upon fee. A drawback of public warehouses is the lack of control by users (for example, users may not be able to receive deliveries to the warehouse after hours).

Bonded storage refers to the situation in which stock is not released until a certain fee is paid. Bonded storage warehouses are used by the US Customs and Border Protection or by the Internal Revenue Service to hold stock until taxes are collected.

Private Warehousing

Private warehouses are owned or leased on a long-term basis by the user. The users need to have high volume of demand to offset the high fixed set-up cost. In addition, the expected demand should remain stable for a long period of time. Once a private warehouse is established, it is costly to abandon or relocate.

Contract Warehousing

Contract warehousing is an outsourcing strategy to acquire warehousing expertise and services of a third party. The warehousing service provider serves an exclusive user for a long term. Depending on the contract, the user/owner and the third-party service provider may share the cost risk. Contract warehousing represents a compromise between public and private warehousing in term of user control, flexibility, and cost.

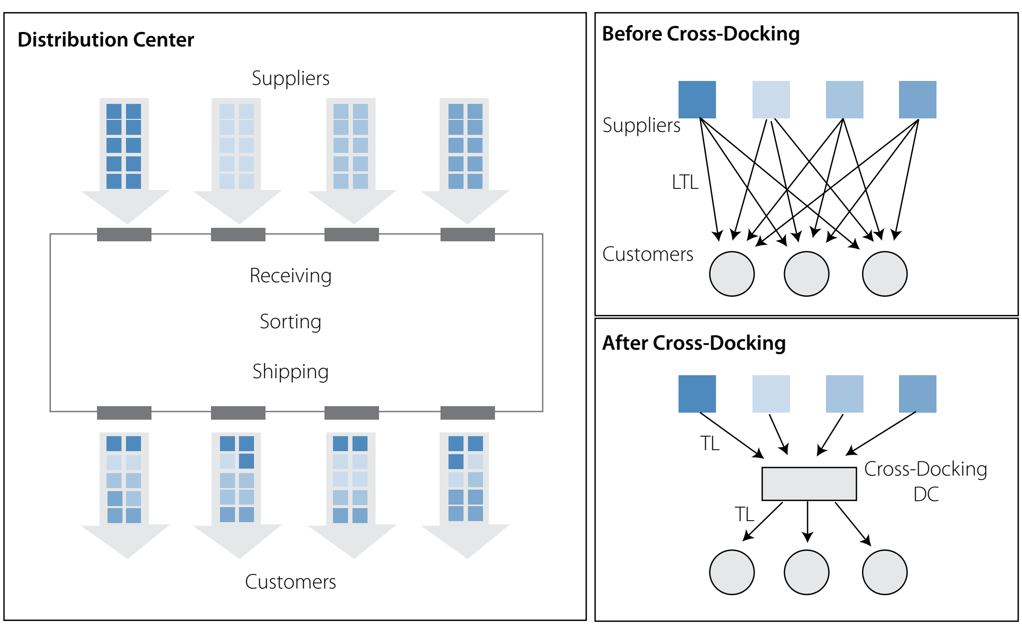
12.2.2 Distribution Centers

Distribution centers (DCs) are specialized warehouses that focus on throughput, a critical function in the supply chain. For example, a regional distribution center for Walmart has the primary role of passing the products it receives to local Walmart stores.

At DCs, one of the prominent practices in recent years is cross docking. Products are received at the receiving dock and are moved directly to the shipping dock, where they are loaded onto outbound vehicles for distribution. The practice of cross docking minimizes storage time. Figure 12-2 illustrates cross docking operations. *(3)* Several vehicles arrive from different manufacturers at about the same time. The products are then combined into different outbound shipments. The left side illustrates a physical layout, while the right side illustrates flow of supplies (and to some extent transportation requirements) with and without cross docking. In this example, the cross dock plays a role of consolidation.

Cross docking requires more dock space for operations than in other warehouses, but it has the convenience of combining the inbound traffic into outbound shipments and minimizes the vehicle and inventory holding time. A popular strategy for the distribution of retail products, cross docking requires strict schedules for both inbound and outbound shipments.

Figure 12-2 Cross docking operations



SOURCE: Rodrigue, J-P et al. (2008). *The Geography of Transport Systems,* Hofstra University, Department of Economics and Geography. people.hofstra.edu/geotrans. Reprinted with permission.
LTL—less than-truckload
TL—truckload

12.3 Inventory Management

Inventory management is one of the most studied warehousing management strategies because of the often substantial cost to carry inventory. A common rule of thumb for estimating the annual inventory carrying cost is 20% of the average inventory value. The overarching goal of inventory management is to minimize the amount of inventory while still satisfying demand. Numerous inventory management models are available, some of which will be introduced in a later section. Note that inventory management strategies are to a great extent industry specific. For example, the computer industry has been characterized as following the assemble-to-order (ATO) model, also called the demand-driven production/inventory model, in which computers are assembled according to specifications in the orders as they are received. In an ATO system, inventory management means setting inventory policies that minimize the stock of various components while still satisfying the demand for assembled products.

Another popular supply strategy involves just-in-time (JIT) deliveries, in which the inventory supply is provided only when it is needed. This strategy was introduced by the Ford Motor Company *(4)* and was later adopted by Toyota Motor Corporation. JIT strategies evolved in the auto industry because the inventories are particularly expensive, heavy to move, and require significant storage space.

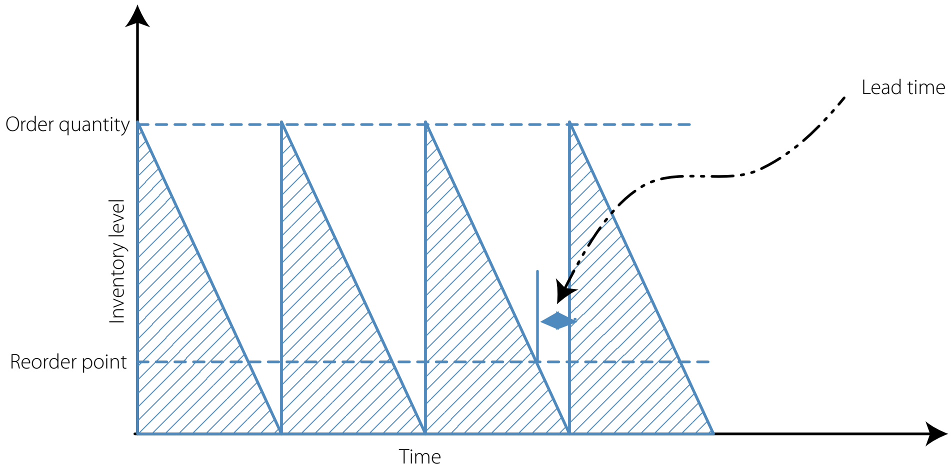
Successful implementation of a JIT system requires cooperation and responsiveness from suppliers. Simply put, it is about having the right materials, at the right time, in the right place, and in the right quantities. Suppliers often locate in the vicinity of a manufacturing plant to ensure responsiveness. A disadvantage of JIT systems is their vulnerability to disruptions in production if suppliers fail to meet demand and standards. Components supplied through a JIT arrangement must be of high quality as little buffer inventory is available to replace damaged or faulty parts.

Inventory management is based on cyclic patterns. (See Figure 12-3.) For example, consider a computer store that has 200 personal computers in stock. Over time, the stock drops at a rate of 10 computers sold per day. If the time for the supplier to process and deliver the order (e.g., the lead time) is two days, then when the inventory reaches 20 computers, the computer store places an order for another lot of 200 units. In two days, when the computer store's stock is completely depleted, the new order arrives, bringing the inventory back to the full level.

In terms of inventory management, this process included the following elements:

- *Supplier:* The party who supplies products or materials to replenish inventory at a warehouse.

➤ **Figure 12-3** Cyclic pattern of inventory



- *Distributor:* The party who manages a warehouse and sends products to retailers.
- *Reorder point:* The inventory level at which an order is triggered and placed with the supplier. In the example above, the reorder point is 20 units.
- *Order quantity:* The amount ordered to replenish the inventory each time the inventory reaches the reorder point. In the example above, the order quantity is 200 units.
- *Order placement:* The administrative work involved in making the order.
- *Stockout:* A situation that occurs when a product is not available to satisfy a customer's demand.
- *Safety stock:* Extra inventory to hedge against stockout. If the demand runs as expected, the safety stock would not be used. Safety stock ensures that customers' (unexpectedly high) demand would be satisfied at a desired probability.
- *In-transit inventory:* The inventory being shipped en route.
- *(s, S) policy:* A popular inventory management policy in which *s* refers to the reorder point and *S* the order-up-to level. The order quantity is *S*. In the example, *s* is 20 units and *S* is 200 units.

If demand occurs at a constant rate, the inventory level follows a uniform cyclic pattern as in Figure 12-3. A cycle length is the time from zero inventory to the next zero inventory. In this case, we can say that the average inventory level is half the order quantity. As a rule of thumb, the average inventory multiplied by the cycle length equals the area under the positive inventory curve and above the time axis during a cycle. In the example of computer inventory, the average inventory over time is 100 units.

The aim of inventory management is to minimize the overall cost. There are several cost items of significance to inventory management, including the following:

Inventory holding cost—The inventory holding cost accounts for the opportunity cost of the capital invested in the inventory, the operational costs for maintaining and insuring the inventory, taxes on the inventory, and losses for shrinkage and obsolescence. In some industries, the obsolescence cost is very high. In the computer industry, where products are updated frequency, the annual inventory holding cost can be as high as 30% of the average inventory value.

Ordering cost—The ordering cost is incurred each time an order is placed to replenish inventory. It includes the administrative cost for paperwork and for arranging transportation (if applicable), and labor cost for order receiving. Because ordering cost does not include freight cost, the ordering cost per transaction does not change with order size. The ordering cost can be estimated by labor hours and the associated wage rate.

12.3.1 Economic Order Quantity Model

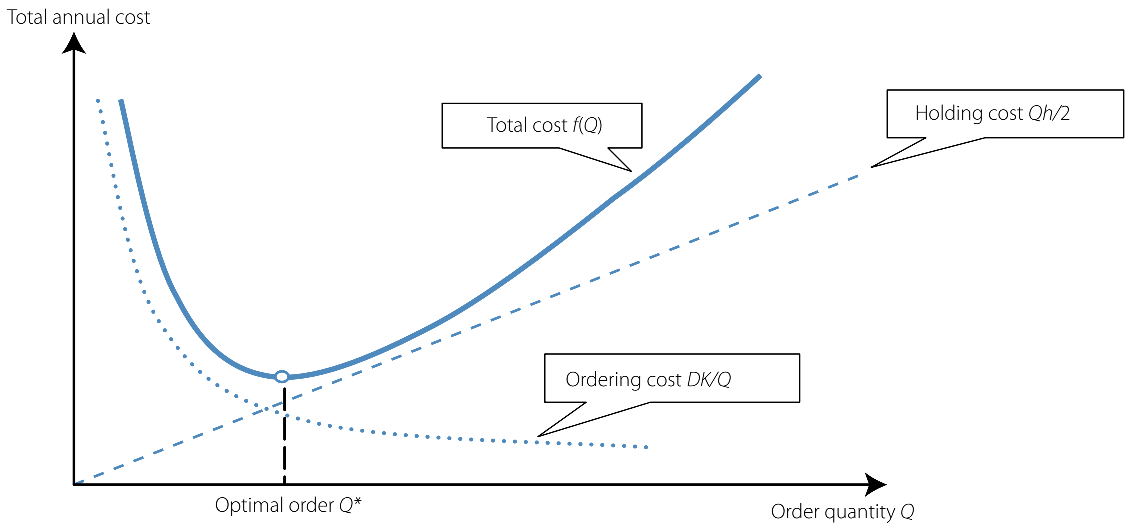
Among the models to minimize the total inventory management cost, the economic order quantity (EOQ) model is the simplest. *(5)* It explicitly considers the inventory holding cost and ordering cost. The ordering cost is a fixed cost associated with placing an order, which includes direct labor time and cost for paperwork, equipment leasing (e.g., for shipping), documentation of ordered items, and unloading. If less is ordered each time, the average inventory will be lower. Consequently, the inventory holding cost decreases. The EOQ model balances between the ordering cost and inventory holding cost by deciding the optimal order quantity.

We will use the following notation in the EOQ model: D = annual demand expressed in units of the product; K = fixed ordering cost per lot; h = inventory carrying cost per unit product; Q = order quantity per lot; and Q^* = optimal order quantity.

Based on Figure 12-4, the annual ordering cost is DK/Q; the annual inventory holding cost is $Qh/2$; the purchasing cost is a constant C to satisfy the demand D, which is ignored in the analysis. Therefore, the total cost as a function of order quantity can be expressed as follows:

$$f(Q) = \frac{DK}{Q} + \frac{1}{2}Qh \qquad (12.1a)$$

Figure 12-4 EOQ model



Setting the first order derivative with respect to Q of equation (12.1a) equal to zero, the optimal order quantity Q^* can be obtained as follows:

$$Q^* = \sqrt{\frac{2DK}{h}} \qquad (12.1b)$$

Figure 12-4 illustrates how the EOQ model balances the trade-off between the ordering cost and inventory holding cost to find the optimal order quantity that minimizes total cost. The inventory holding cost $Qh/2$ increases at a constant rate with order quantity, Q. Increasing the order quantity reduces the frequency of ordering so the total ordering cost DK/Q decreases. Total cost is the sum of the holding and ordering cost. The optimal order quantity occurs at the minimum total cost.

Example: A distribution center manages distribution of a product with unit cost of \$50. The annual demand for this product through the distribution center is 4,000 units. The cost of placing an order for any number of units is \$400. If the inventory carrying cost is 20% of the inventory value, what is the optimal number of units per order that will minimize total holding and ordering cost?

Solution: Given D=4000, K=400, and h=\$50*0.2=\$10.00/unit,

$$Q^* = \sqrt{\frac{2KD}{h}}$$
$$= \sqrt{\frac{2 \cdot 4000 \cdot 400}{10}}$$
$$\approx 566 \text{ (units)}.$$

The optimal order size is thus 566 units. Notice that as the ordering cost goes up, the optimal order size goes up. The order frequency is determined from the total annual demand and order size.

The EOQ model does not capture the effect of freight cost. By assuming the ordering cost is fixed, we assume the transportation cost is also fixed over a reasonable range of feasible order quantities. Hence a slight change in freight cost would not significantly affect the ordering policy. The model effectively assumes that freight cost is negligible compared with inventory cost. For situations where freight costs are of concern, the analyst should modify the ordering cost term in equation (12.1a).

Shipping time has an impact on the safety stock and therefore affects the average inventory.

The EOQ model applies in cases where lead time and market demand are relatively stable. A longer lead time together with a larger uncertainty would increase the risk of a stockout and necessitate the need for more safety stock. Many approaches are available for quantifying the impact of uncertain demand and lead time on inventory. *(6)* The resulting inventory usually comprises the quantity prescribed by the EOQ model and an additional buffer stock.

An advantage of the EOQ model is its simplicity, ease of application, and robustness. A large deviation from the optimal order quantity causes relatively small increases in the total cost compared with minimum cost. For example, if there is a large error, say 50%, in demand forecast, the increase in the total ordering and inventory holding cost may only be a single digit percentage. This can be easily illustrated with equations (12.1a) and (12.1b). By substituting the optimal order quantity back into equation (12.1a), we can calculate the total cost, $f(Q^*) = \sqrt{2\,DK/h}$. If we change the order quantity to be $Q = \alpha Q^*$, varying the order quantity by a factor α, we have the total cost $f(Q) = (1/2\alpha + \alpha/2)\sqrt{2DK/h}$, which determines the total cost with a deviation in the order quantity from the optimal EOQ. If $\alpha = 1.5$, we still have $f(Q) = 13/12\, f(Q^*)$, an increase of cost by about 8% compared with the optimal case.

12.3.2 Dealing with Uncertainty in Demand and Lead Time

Both lead time and demand are random processes. The reorder point must be set high enough to satisfy demand during the lead time and to account for uncertainty. Thus, the reorder point has two parts, one of which satisfies regular demand during the lead time, while the other accommodates irregular demand during the lead time. This additional stock to satisfy irregular demand is called safety stock.

We use the previous example to help understand safety stock. The regular demand during the lead time is 20 units. An irregular demand during the lead time follows a probability distribution function; the reorder point is 20 units plus a safety stock. If everything goes as expected, 20 units of stock would be enough for the demand and the safety stock would be intact. The safety stock is set at a level such that the probability that the irregular demand can be met with this safety stock is α. Here α is referred to as service level.

When safety stock or the reorder point is set too low, the stock depletes too quickly, causing a stockout situation to occur. There are several possible customer reactions to a stockout. The customer could come back at a later time; the customer could go to a competing store and be lost forever; or the customer could commit to a future purchase of the item from this store. Each of the three outcomes has an expected benefit and cost to the retail store. By carefully judging the probability and cost for each outcome, a stockout cost per unit demand is determined. Knowing the stockout cost is useful for deciding the right safety stock level.

12.4 Warehouses in the Supply Chain

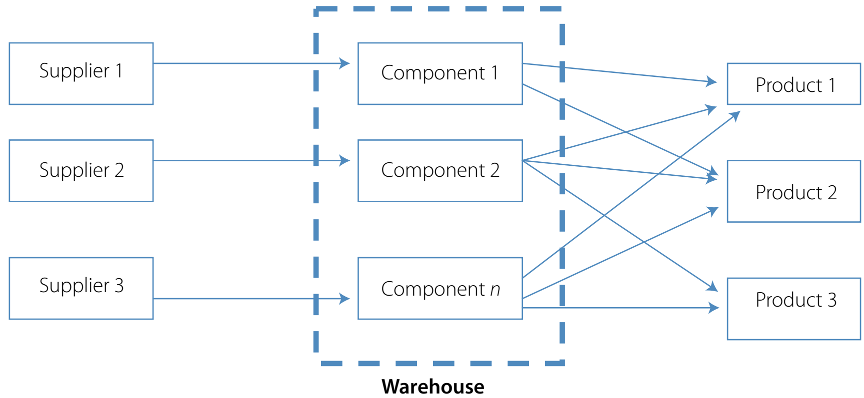
Warehouses and distribution centers form a network of nodes connected by lines (e.g., freight lanes and major ports and terminals) to suppliers, manufacturers, and markets. Supply chains are interwoven on this network. The agility of a supply chain depends on the intrinsic nature of the network, within the supply chain following the geographic distribution of resources and strategic partnerships. The network is critical to the efficient distribution of materials and products and allows suppliers to promptly respond to market changes.

If products get manufactured according to a prearranged scheduled, the products are pushed down the line of supply. This corresponds to the so-called push supply chain system (or make-to-stock). If product manufacturing does not start until the demand is known—e.g., the manufacturing is driven by demand—and the products are shipped to satisfy a specific demand, it is called a pull supply chain system (or, make-to-order). Current practices are shifting from push systems to pull systems.

An example of a pull system is shown Figure 12-5. The figure shows a special form of production supply chain, called an assemble-to-order system. In this example, the warehouse serves the role of an assembly plant.

The assemble-to-order system is popular in the computer industry. Components of a computer, such as memory chips, keyboards, and monitors, are delivered to a warehouse for assembly. The computers do not get configured un-

Figure 12-5 Pull supply chain system



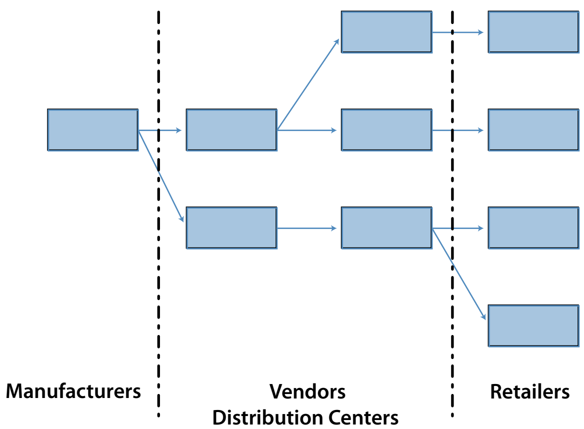
til an order is received from a customer, allowing the computer to be configured to the customer's specifications. The assemble-to-order system has proven to be effective in reducing obsolescence cost in the computer industry.

The multi-echelon system of distribution is another effective supply chain model. In the distribution system sketch in Figure 12-6, the product is manufactured at a plant. The manufacturer is the most upstream echelon. The product is then supplied to the immediate next echelon, a distribution center. The distribution center further distributes the product to the vendors. Retailers, the most downstream echelon, receive the product for sale.

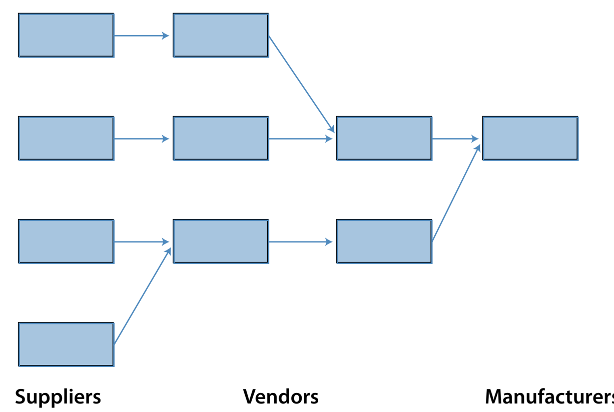
The organization of a multi-echelon system of assembly is illustrated in Figure 12-7. Components are assembled into semiproducts, which are shipped to assembly plants for final production. The supply chain for the auto industry is a good example of a multi-echelon system of assembly. Engines, electronics, and other parts are assembled at different locations and shipped to a central assembly plant for final production.

Multi-echelon systems of distribution and assembly are strategies to enhance supply chain integration and smooth the flow of inventory for system efficiency. Measures to improve supply chain stability include overpurchasing and overproducing. The so-called bullwhip effect occurs in an unstable supply chain when each upstream echelon tends to order more than demanded by its downstream echelon in an attempt to cover uncertainties and maintain a high level of service. The whip occurs when each upstream echelon over orders in response to the overestimated downstream demand resulting in overproduction across the entire chain. Tight coordination between the echelons reduces the tendency to overorder. *(7)* There are strategies to facilitate collaboration between echelons. For example, a distributor and a retailer could implement a buy-back policy, which requires the distributor to buy back unsold products at a preset discounted rate. A correctly set discount rate for the buyback creates a disincentive for the distributor to push inventory to the retailer and an incentive for the retailer to share accurate demand information.

➤ **Figure 12-6** Multi-echelon system of distribution



➤ **Figure 12-7** Organization of a multi-echelon system of assembly



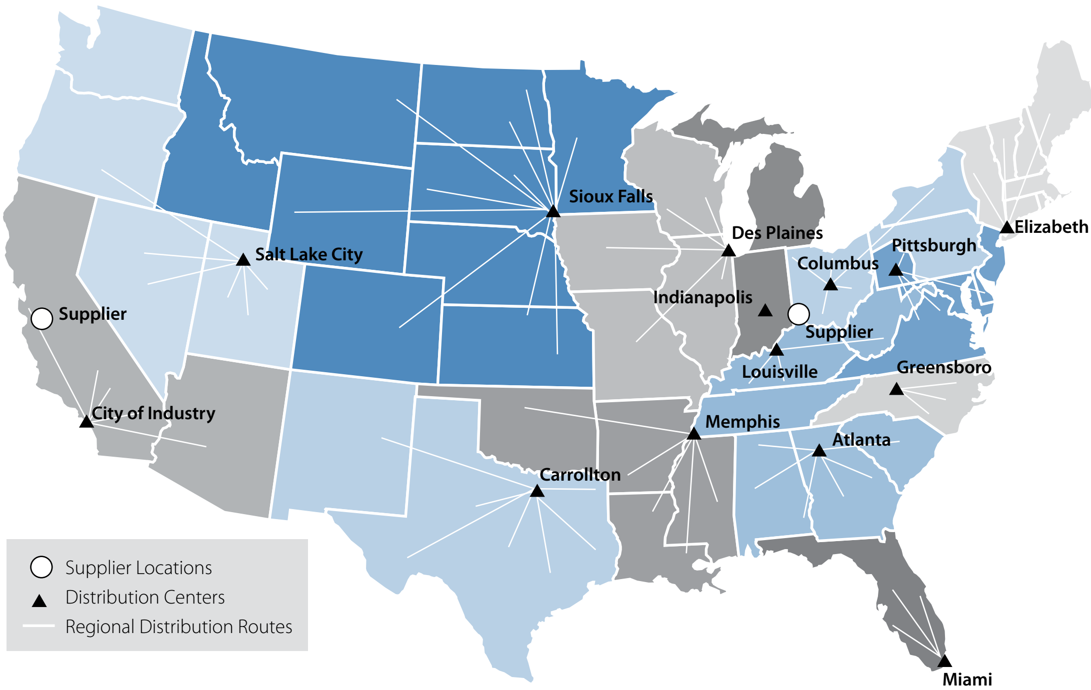
From a public freight planner's perspective, one might simply consider the links between echelons as the shipping lines and freight terminals of the overall freight transportation network. However, the links at different levels of the echelon have different significance in terms of the overall network performance. For example, the transportation links from manufacturers in East Asia to distributors on the West Coast may be more critical than those connecting distributors to retailers. Delays and associated costs during ocean shipping and at West Coast ports will have an impact on product distribution in the entire US market. To freight planners, strategic focus on trunk freight lanes, arterial freight corridors, and major freight terminals improves the reliability and performance of the numerous supply chains that depend on them.

12.5 Warehouse Location and Distribution Network

Warehouses and distribution centers do not function in isolation; they form nodes of a distribution network mapped onto the modal transportation system. The location of each particular warehouse matters in the context of collective market coverage. A national or global distributor must consider two related questions: where to locate a warehouse, and how to form an efficient distribution network. The answer to the first question largely depends on the second. The important characteristics of a distribution network include

- Response time to market,
- Product variety and availability to customers,
- Order visibility,
- Level of centralization in operations, and
- Transportation capacity and accessibility.

Figure 12-8 Illustrative distribution network for a national air express courier



The first characteristic depends on proximity to market. Product variety and availability to customers will dictate the supply chain strategy and functions of the distribution network. Order visibility depends on how the retailers, distributors, and suppliers are integrated through partnerships and information sharing. Level of centralization refers to the extent to which the individual distribution centers collaborate in complementing each other's market coverage. Transportation availability at warehouse locations significantly impacts transportation costs and a distributor's ability to respond to market. Figure 12-8 illustrates a distribution network.

12.5.1 Center-of-Gravity Model

The center-of-gravity (COG) model helps determine the optimal location for an individual warehouse if proximity to customers is the only criterion. To select a site for an individual distribution center to serve local customers, the model finds the location closest to the center of demand for all customers. Customers are assumed to be located on a grid system, each with a given fixed annual demand. The location of each customer is represented by an x and y coordinate. The center-of-gravity model is a weighted approach that locates the warehouse closest to customers with highest demand. The model finds the (x, y) location that minimizes the distribution distances weighted by shipping volume using the following formula:

$$x = \frac{\sum_i x_i d_i}{\sum_i d_i} ; y = \frac{\sum_i y_i d_i}{\sum_i d_i} \tag{12.2}$$

Where x, and y, are the coordinates of the ith customer, and d_i is annual demand of the ith customer.

Example: The ABC Company would like to set up a distribution center to serve several key supply chain customers in the area. The annual demand and the location of these customers are shown in the table below. The COG model is used to determine an approximate location of the distribution center.

Table 12-1 Example customer and demand details

Customer	Location (*x,y*)	Annual Demand (units)
A	(5, 12)	2,000
B	(7, 8)	10,000
C	(12, 10)	4,000
D	(3, 9)	15,000
E	(15, 4)	6,000
F	(7, 15)	8,000
Total		45,000

Solution: The optimal warehouse location is calculated as follows.

$$x = \frac{\sum_{i=1}^{n} x_i d_i}{\sum_{i=1}^{n} d_i} = \frac{(5\cdot 2000)+(7\cdot 10000)+(12\cdot 4000)+(3\cdot 15000)+(15\cdot 6000)+(7\cdot 8000)}{45000} = 7.09$$

$$y = \frac{\sum_{i=1}^{n} y_i d_i}{\sum_{i=1}^{n} d_i} = \frac{(12\cdot 2000)+(8\cdot 10000)+(10\cdot 4000)+(9\cdot 15000)+(4\cdot 6000)+(15\cdot 8000)}{45000} = 9.4$$

The location at $x = 7.09$ and $y = 9.4$ is a starting point for consideration for a warehouse that will best be sited to respond to market demand. The COG method does not, however, consider zoning requirements, land prices, warehouse taxes, labor availability, or other factors.

12.5.2 Distribution Network

The location of distribution centers depends on the product market. For consumer goods, the distribution network is heavily influenced by the geographic distribution of the consumer population. Consequently, for long-term freight system planning, it is critical to be able to gauge any geographic shifts of population, which cause changes to the distribution network in the private sector, which in turn shifts the burden on the infrastructure system planned and operated by the public sector.

An important decision in a distribution network is the number of distribution centers. The more distribution centers in a network, the closer the network is to its market. However, more distribution centers also means fewer economies of scale in warehousing operations and trunk line shipping. The supply chain planner is responsible for determining the number of distribution centers and their locations.

12.5.3 Capacitated Plant Location Model

The capacitated plant location model is an advanced approach to distribution network optimization. The model assumes a set of customers, each with a known demand. The locations for a number of plants are to be selected from a set of available sites, each incurring a fixed cost. The objective is to select the right plant locations to satisfy the customer demand and minimize the overall cost, including setup and operations. *(8)*

The capacitated plant location model uses following notation:

n Number of potential plant location sites,

m Number of markets or demand points,

d_j Annual demand from market j,

K_i Capacity of plant i,

f_i Fixed annual cost of keeping plant i open, and

c_{ij} Cost of producing and shipping one unit of product to market j from plant i.

Two decision variables of the model are defined here:

y_j equals 1 if plant i is open, 0, if otherwise; and

x_{ij} is the quantity shipped from plant i to market j.

The capacitated plant location model formulation is an integer programming problem.

$$\text{Min} \quad \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \tag{12.3}$$

Subject to

$$\sum_{i=1}^{n} x_{ij} = d_j, \text{ for all } j = 1,2,\ldots,m, \tag{12.4}$$

$$\sum_{j=1}^{m} x_{ij} \le K_i y_i, \text{ for } i = 1,2,\ldots,n, \tag{12.5}$$

$$y_i \in \{0,1\}, \text{ for all } i = 1,2,\ldots,n. \tag{12. 6}$$

The objective function (12.3) minimizes the total location and operating costs. The constraint (12.4) ensures all demands are exactly satisfied. Constraint (12.5) is the capacity constraint from each plant. Constraint (12.6) assures that all plants are either open or closed. The model can be solved with commercial integer programming software. However, when many integer variables y_i are involved, the solution could be cumbersome, often requiring heuristic methods.

The capacitated plant location model captures the parameters of a typical network design problem. The costs for shipping to markets and for production and facility locations are of primary consideration among the costs that can be controlled. Potentially feasible locations are identified. Market reallocation is a function of the existing distribution center locations.

12.6 Summary and Future Trends

Early warehousing and distribution began as independent activities. Today, they are integral to the supply chain, linking input materials and parts to final products for consumers. No longer simply providing for storage and distribution functions, modern warehouses and distribution centers have critical roles in making the process from inputs to consumption as efficient as possible.

In this chapter, we introduced the concepts of warehousing operations and distribution network design. Central to warehousing operations is inventory management. Two critical parameters of an inventory policy are reorder point and order quantity. The economic order quantity (EOQ) model presented here is the most basic and robust. Zipkin *(5)* and Song and Yao *(1)* provide more theories and developments. A new trend is to integrate pricing with inventory management to maximize potential revenue, and lower inventory cost.

The distribution system is characterized by location and coordination among a group of warehouses. We presented simple location models for a network of distribution centers. These models become more complex when we consider implications of freight volumes, frequencies, and sensitivities to congestion and delay.

Warehousing operations are part of the multi-echelon supply chain systems for assembly and distribution. The multi-echelon systems presented here are simple and basic. More advanced theories and practices are beyond the scope of this chapter. Stability of these multi-echelon systems depends on partnerships between supplies, manufacturers, and retailers. Cooperation arrangements in the form of risk or profit sharing can make the supply chain more responsive to market changes.

12.6.1 Trends in Warehousing and Distribution

There are several trends in warehousing and distribution worthy of special mention here. First, the activities are more and more integrated. Relationships between suppliers, distributors and retailers are becoming more transparent through digitalization, data sharing, and partnerships. One simple example is package and shipment tracking. With GPS, GIS, RFID, and establishment of sensor nets for freight movement, shippers have improved their ability to continuously monitor the movement of cargo in the system. This has led to tremendous opportunities for integrating production, warehousing/distribution, and retail. Second, the scale of optimization has increased. Optimization and reoptimization are being done in (quasi-) real time. For example, a national chain store reoptimizes its distribution system every six months in response to demand changes. Third, the application of information technology has enabled the system to differentiate fast-moving products from slow-moving products, and this information is used to allocate storage space and develop appropriate ordering policies.

12.6.2 Trends That May Affect Warehousing and Distribution

Many factors are reshaping the national and global distribution of products. These factors include volatile fuel prices, national policies to reduce greenhouse gas emissions, and currency exchange rates. As freight costs rise, global manufacturing companies tend to pull their manufacturing functions closer to the end consumers. Other factors that influence global sourcing decisions are political and economic stability. *(9)*

Carbon emissions associated with the movement of goods from suppliers to manufacturers, manufacturers to distributors, and distributors to retailers have a significant impact on the carbon footprint of any supply chain. Consequently, there has been increased pressure to institute practices that increase the energy efficiency (and corresponding reduction in carbon emissions) of logistics operations. *(10)* Recent emphasis on using more energy-efficient vehicles or more efficient modes of transportation will reduce carbon emissions, but they do not address the fundamental transportation requirements of supply chains. Alternatively, the carbon emission problem can be addressed by restructuring the role of transportation in the supply chain. Supply chain practices that rely on just-in-time deliveries and lean principles exchange inventory holding for frequent deliveries and smaller shipments, often less than a truck load. Carbon emissions remain high without a change in supply chain practices. This approach calls for rethinking the design and operation of supply chains, examining the accountability of individual members of the supply chain for their carbon footprint, and providing incentives and regulatory policies that encourage choices to reduce the carbon footprint of the entire supply chain.

In addition, new e-business models are challenging the traditional distribution channels through warehouses and distribution centers and the traditional partnerships. The e-business models enable direct sales and shipping, which have energy and environmental implications. Future trends will likely present significant new opportunities and challenges to understanding freight demand, especially the factors causing freight demand to peak, shift, and change. A good understanding of freight demand is essential to the success of long-term freight planning efforts.

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13

Freight Transportation Planning

Michael D. Meyer and Hsing-Chung Chu

13.1 Introduction

The movement of freight has historically been viewed by public officials as primarily an issue for private companies. In part due to restrictions imparted on state (and thus local) governments by the Interstate Commerce Clause of the US Constitution,[1] as well as constraints in many states on the use of public funds that might benefit one private organization over another, public officials have shied away from public investments that would directly benefit rail, trucking, air cargo, or maritime companies. However, beginning in the early 1990s, and especially with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, more attention has been given by public officials to the role and impact of freight movement on transportation system performance. In addition, a growing awareness of the contribution of the freight and logistics industries to state and local economies has led many public officials to focus more attention on how freight movement can be made more productive and less intrusive in the community. The purpose of this chapter is to describe how freight considerations can be included in the statewide and metropolitan transportation planning process, the challenges of doing so, and the types of strategies and projects that would typically result.

1 The Interstate Commerce Clause of the US Constitution says that Congress has the power to regular commerce "among the several states." This is often interpreted that unless Congress explicitly legislates actions constraining interstate commerce, state and local governments do not have the right to do so.

13.2 Why is Freight an Issue for the Transportation Planning Process?

Other chapters in this book provide statistics that show the importance of the freight sector to the national economy, and thus they will not be repeated here. (See Chapters 1 to 3.) However, this important linkage between the movement of freight and economic vitality is a major reason why public policy and the planning process should be concerned about an efficient and productive freight system. Given that one of the most stated reasons for public investment in the transportation system is to motivate, enhance, and stimulate economic development, the linkage between transportation planning and freight concerns becomes self evident. *(1)* However, there are many other reasons why freight issues should be considered in the transportation planning process.

Infrastructure Sharing. The intermodal nature of freight movement usually means that at least one portion of a trip will be made on the highway network in a truck. Trucks use the same roads as passenger vehicles and thus contribute to congestion and the physical deterioration of bridges and road surfaces. Given that, to a large extent, public agencies provide, operate, and maintain this road network, it is not surprising that public officials are concerned about network performance and those factors that contribute to its deterioration. This sharing of the transportation right-of-way is also an issue with commuter rail services running on private track, air cargo planes landing at public airports, and ships using navigational channels that are maintained by the US Army Corps of Engineers.

Environmental Quality. One of the most important characteristics of transportation planning over the past 40 years has been an increasing reliance on transportation strategies for achieving many environmental goals. Whether the environmental issue is air quality, climate change, noise, community disruption, energy conservation, or public health, a major focus has been placed on modifying some aspect of the transportation system or of the vehicles that use it in order to reach an environmental goal. Thus, for example, engine technologies that reduce the emission of diesel fuel particulates or that rely on new forms of energy have been applied in all of the freight industries (for example, the “clean” locomotive). The environmental footprint of the freight sector is an important consideration in a transportation planning process targeted on enhancing the environmental quality of the community. (See Chapter 18.) This footprint will likely become even more important in future years as governments at all levels implement strategies to reduce greenhouse gas emissions, to which the freight sector is a major contributor.

Land Use. The relationship between land use and transportation is another issue that motivates the consideration of freight in transportation planning. Transportation investments can have a significant influence on land use patterns and urban form. Similarly, where land uses occur in a community can influence transportation system performance through the travel demand generated on the local road and transit networks. Freight activities, such as intermodal yards, rail terminals, ports, air cargo facilities, and warehousing/distribution centers, often require intensive land use. Thus, not only do these activities consume a lot of land (an issue to many community planning agencies), but their size and location can place significant pressures on local road networks through the truck volumes generated by the activity.

Future Transportation Flows. The transportation planning process fundamentally deals with the characteristics of future travel flows. Where will the bottlenecks be in the transportation system in 20 to 25 years? Given expected land use changes, where are new transportation facilities and services needed? What will be the likely impacts on the local road network and on the community of a major new intermodal yard? These and similar questions serve as the foundation of the planning process. Numerous studies and forecasts have shown that the fastest growing user-group of the nation's transportation system is the freight sector, especially trucks, particularly due to increasing trade flows. *(2)* Thus, transportation planners concerned about forecasting future system performance must necessarily consider future freight flows in their community if they are to paint a valid picture of what their transportation system will look like in some future year.

The above reasons for including freight concerns in transportation planning relate to the more general planning processes that examine all forms of transportation in a state or metropolitan area. In some instances, agencies undertake freight-specific planning efforts. To give a sense of why such planning is undertaken, the following examples illustrate some of the often stated purposes of a freight transportation plan.

The New Jersey Department of Transportation says its Comprehensive Statewide Freight Plan

- Describes the goods movement transportation network in New Jersey from a physical, operational, economic, and citizen's perspective.
- Produces a synthesis of previous work and outreach highlighting issues, trends, challenges and opportunities in goods movement in New Jersey.
- Identifies, evaluates and recommends alternative options/policies that address constraints by mode.
- Increases public understanding of the goods movement and logistics issues.
- Develops better tools and performance measures to evaluate freight issues and options.
- Strengthens partnerships and coordination with sister transportation agencies, other government organizations, private industry and the public. *(3)*

The New York Metropolitan Transportation Council says,

> The purpose of the New York Metropolitan Transportation Council (NYMTC) Regional Freight Plan Project is to develop a roadmap for the improvement of freight transportation in the NYMTC region. The plan presents a wide range of strategies and actions that include capital projects, operational improvements, and policy changes. These strategies are multimodal, targeting highway, rail, and marine transport, and can be implemented in the short term (one to three years), mid term (three to 10 years), or long term (more than 10 years). *(4)*

The goals of the Maine Department of Transportation plan are to:

- Develop an updated freight profile for Maine reflecting changes to the freight transportation system and the evolution of the freight transportation industry;
- Build relationships with and identify the concerns of public and private freight stakeholders in the State;
- Document the progress and lessons learned since the completion of the original Intermodal Freight Plan (IFP) in 1998; and
- Recommend specific freight improvement projects and changes to Maine's freight planning program. *(5)*

According to the City of Seattle, its plan

> [S]erves as a guide for the Seattle Department of Transportation's freight mobility activities, with both near-term and long-range goals and action items. This Action Plan is an important accountability tool for commitment to the movement of essential goods and services critical to our City and regional economy. *(6)*

Whether examining freight movements as part of a more general transportation planning process or conducting a freight-specific planning effort, the planning process often consists of similar tasks. The next section discusses the steps that are commonly followed when conducting a transportation planning process.

13.3 What is the Transportation Planning Process?

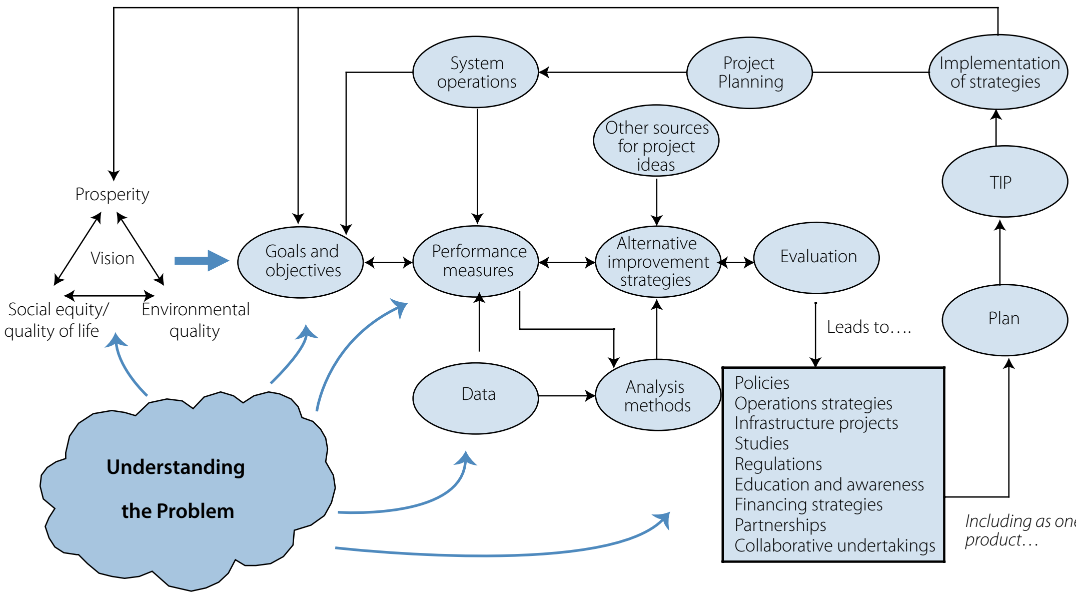
At its very basic level, the intent of any transportation planning process is to produce information that can be used to make decisions for improving transportation system performance. These decisions can relate to issues of statewide concern, focus on metropolitan-level challenges, or deal with community- or local-level problems. In the United States and in many other countries, the national government requires that transportation planning occurs on a periodic basis so that investments in the transportation system will be informed of the likely benefits and costs associated with these decisions. For example, the US federal government requires there to be an organization called the metropolitan planning organization (MPO) in every urbanized area with a population of more than 50,000 that is responsible for conducting the transportation planning process and developing a transportation plan for that area. Federal law requires there to be a statewide transportation planning process as well, resulting in a statewide transportation plan (although the requirements for the statewide planning process are not as stringent as those for the metropolitan planning process).

In addition to the development of statewide or metropolitan transportation plans, the transportation planning process undertakes a variety of other planning tasks that could be relevant to freight interests. Studies at various geographic scales are done to focus on the problems facing a state, region, or specific locale in a community. For example, corridor studies are commonly undertaken that examine the transportation and land use issues in well-defined transportation corridors. Some corridors are relatively small, located well within an MPO study boundary, whereas others are quite lengthy and include multiple states. Planning agencies also undertake sector- or mode-specific studies whose intent is to identify the key issues affecting system performance. For example, many state departments of transportation (DOTs) have produced statewide plans on intercity freight movement, the airport system (including general aviation airports), the rail network, and maritime and port facilities. Some planning efforts are even more targeted, such as developing a plan for improving highway-railroad grade crossings. Many MPOs have conducted studies on metropolitan freight and goods movement studies, port access, truck use of the regional freeway network, and area-specific freight bottlenecks such as at major warehousing/distribution centers. Each of these planning efforts has a very strong freight component and thus a need for freight stakeholder involvement in the planning process.

Transportation planning can be viewed as consisting of several major steps (see Figure 13-1), each of which has an important place in freight considerations. A transportation planning study usually begins with some effort to understand the problems facing a study area. These problems will vary according to the specific issues facing a jurisdiction, as well as by the purpose(s) of the study effort. Some of the more common "problems" identified by transportation studies include: road congestion, crashes (actual and potential), poor accessibility to different parts of the study area, inadequate transportation services to different population groups, environmental impacts such as pollutant emissions or degradation of water quality, and sprawling land use patterns induced by transportation investment.

Given an understanding of the challenges and problems facing the transportation system and community, the next step in the planning process is to establish some sense of what the desired outcome of a transportation plan or study might be. This outcome could be defined as a set of desirable system performance characteristics, or as a desired community vision. Often, the transportation planning process includes a visioning effort that involves a range of stakeholders and public participants. This effort almost always leads

Figure 13-1 The transportation planning process



SOURCE: *Urban Transportation Planning: A Decision-Oriented Approach.* (19)
TIP—transportation improvement program

to the identification of a set of study goals and objectives that serve as a means of influencing the evaluation of the actions and strategies that will be considered during the planning process. Thus, for example, if a study goal is to promote economic development through investment in the transportation system, then it is likely that one or more of the criteria for evaluating different actions will be the degree to which each action contributes to economic development. A recent development in the transportation planning field is the use of performance measures as a means of monitoring the change in system performance and condition over time. Such measures focus on a targeted set of issues that are of greatest concern to those investing in the transportation system, often including measures relating to congestion, mobility, safety, and environmental quality. Performance measures are also strongly connected to the evaluation criteria that are used later in the planning process to assess the relative benefits and costs of plan or project alternatives.

Although transportation planning includes many different steps and responds to a variety of political and organizational influences, its primary purpose is to analyze and evaluate alternative courses of action. As shown in Figure 13-1, the analysis step depends on data collection and the use of analysis tools and models to identify the likely consequences of implementing each alternative under consideration. This analysis has been the foundation of transportation planning ever since the first transportation planning study was undertaken. Analysis tools and models can be very simple, or they can be complex and time-consuming. Much of the research that has occurred in transportation planning over the past several decades has focused on developing new methods and tools for conducting transportation analysis, with special emphasis on understanding and representing travel behavior in transportation systems models.

The analysis process often results in a great deal of information being produced for each alternative. The next step in the planning process—evaluation—uses this information to assess which alternative is more desirable than the others. Given that decisions in the public sector are made by decision makers often subject to a variety of influences and pressures, it is not surprising that the "best" alternative as indicated by the systematic evaluation process is not always the one selected. In fact, many of the recent approaches to evaluation explicitly recognize the political nature of decision making by providing a range of evaluation information, and then letting decision makers use the information that is most relevant to their own concerns and desires. Thus, the type of information provided by the evaluation process ranges from quantitative to subjective, from a focus on numerical benefits/cost indices to a narrative assessment of likely consequences, and from information targeted on the alternative itself to a much broader consideration of equity and distributional impacts of the associated costs and benefits. Given that the evaluation step is where decision makers are provided information on the likely impacts of each alternative, this step is one of the most important in the transportation planning process.

With respect to the products of the planning process, many planning efforts result in a transportation plan or at least a written set of recommended actions and projects. As noted earlier, US federal law requires that each urbanized area and state have such a plan. However, the planning process also results in many more products that would be of interest to both public- and private-sector participants. The planning process can recommend financial strategies, new institutional arrangements, nonconstruction actions such as improved enforcement or improving the transportation awareness of key constituencies, new laws and/or ordinances, etc. The list shown in Figure 13-1 illustrates the many different products that can result from the planning process, each of which benefits from the participation of stakeholders in the process itself.

Another product of the planning process is often a transportation investment program, a document that identifies those projects that will be implemented over some investment timeframe. This investment program usually identifies which agency is responsible for a project, the schedule of implementation, and expected cost. Again, in the United States, both the metropolitan and statewide transportation planning processes are required to have a transportation improvement program (TIP, or STIP for a state program) as a product of the planning process.

The final step in the planning process comes with the implementation of the projects and strategies that were identified during the planning process. This step involves the monitoring of system operations and the identification of problems in the transportation system. This "feedback loop" leads back to the goals, objectives, and performance measures and becomes part of the problem understanding step in the next round of transportation planning. For many transportation planning studies, this feedback loop does not exist—in other words, the study was a one-time effort. However, for statewide and metropolitan transportation planning in the United States, the transportation plan must be updated every four to five years; thus, a formal planning process is undertaken periodically to provide this update.

13.4 Freight Examples for Each Step of the Planning Process

The planning process outlined in Figure 13-1 provides many opportunities for incorporating freight concerns. The following sections provide examples from freight planning studies and from more general transportation planning efforts that illustrate how freight issues have been addressed in the planning process.

13.4.1 Understanding the Transportation Problem

The focus of transportation planning can be on a wide range of transportation problems or challenges facing a community. As noted earlier, at the broadest policy level, these challenges could relate to such things as economic development, transportation system performance, and environmental quality. An example of the type of freight-related challenges and opportunities that could be part of a transportation planning effort is found in the Dallas-Ft. Worth, Texas, metropolitan area. As noted by the North Central Texas Council of Governments (NCTCOG), the MPO for the area, the goals of the region's goods movement program include:

- Promoting North American Free Trade Agreement (NAFTA) safety and mobility issues
- Promoting safety at highway/rail crossings.
- Improve air quality by implementing the Diesel Freight Vehicle Idle Reduction Program
- Establishing new processes for intermodal freight community input
- Monitoring goods movement traffic throughout the region
- Evaluating accessibility of intermodal freight centers
- Ensuring safety of hazardous materials truck routes
- Continuing MPO involvement with freight and NAFTA groups
- Reviewing intermodal factors in project selection for major rail studies and other major investment studies. *(7)*

Although these components of the NCTCOG goods movement program were listed as "goals," in many ways they introduce into the planning process the issues or challenges facing the region, such as safety, air quality, accessibility, NAFTA issues, and planning process reengineering to include freight stakeholder involvement.

Transportation studies also often focus on very specific problems or geographic areas where freight mobility is a concern. Strauss-Wieder surveyed a range of public organizations and private firms that were involved with or concerned about freight transportation. *(8)* Survey participants identified a large number of freight-related issues, with the most important relating to the movements of trucks, followed by rail freight facilities and operations. As can be seen in Table 13-1, many of these issues are identified at a very localized geographic level and are often facility-specific. In such cases, special transportation studies are often undertaken to identify solutions to the specific problems found at a location.

Table 13-1 Community-identified freight issues

Community Identified Issues Relating to Truck Facilities/Operations	Community Identified Issues Relating to Rail Facilities/Operations
• Congestion generated on local roads, highways and at customer facilities • Large tractor-trailers making deliveries to customer facilities—insufficient loading dock space, leading to double parking and street congestion • Movement of heavier trucks on roadways adversely affecting automobile speeds • Damage caused to pavement, especially from heavier trucks and more frequent truck movements on local roads • Hazardous materials spills and accidents caused by truck movements • Accidents involving trucks • Diesel emissions (impact on air quality) derived from truck operations • Truck hours of operation affecting peak period traffic flows • Noise and vibrations generated by trucks • Potentially negative impacts on property values from truck activity • Lack of available truck parking and rest stops resulting in trucks parking on shoulders and along roads, potentially causing safety concerns • Light pollution generated by nighttime operations at loading docks and truck terminals • Potential new development on existing truck terminal properties • Inadequate truck access to maritime and air cargo terminals affecting the competitiveness of these facilities • Inadequate road geometries, turning radii, and turning lanes to accommodate trucks	• Facility shut or rail line abandoned resulting in the area being deprived of service and economic development opportunity • Inadequate capacity to accommodate the rail freight needs of the area • Facility location impedes economic development goals • Hazardous materials spills and accidents resulting from rail freight operations • Other land uses encroaching onto rail rights-of-way • Noise and vibrations resulting from train operations • Diesel emissions resulting from idling locomotives • Lack of a buffer zone around the rail yards • Undesirable odors from the rail yards • Light pollution generated by nighttime operations • Impact on property values along rail rights-of-way from increased train activity and/or lack of maintenance of right-of-way • Inadequate truck access to rail yards • Delays at at-grade crossings and resolving congestion and safety issues • Trespassing on rights-of-way/accidents • Conflicts with commuter/passenger rail service on rights-of-way • Train cars stored on rights-of-way near residences

SOURCE: *Integrating Freight Facilities and Operations with Community Goals.* (8)

13.4.2 Establishing Study Goals/Objectives/Performance Measures

Given the range of purposes that a transportation planning study could serve, it is not surprising that study goals and objectives can vary widely. The intent of a goals and objectives statement is to provide guidance to the planning process on what the ultimate recommendations are to achieve; thus, such a statement is a very important point of departure for the remaining steps in the planning process. Often, transportation agencies spend considerable time reaching out to numerous transportation stakeholders and the general public soliciting input on community goals and objectives that is then reflected in subsequent study steps.

For more general transportation planning efforts, a study's goals and objectives might include a freight-specific statement, but more often than not freight is considered as part of the general intent of the planning effort. For example, the San Diego metropolitan area's regional transportation plan identified the following seven policy goals that were to guide the development of the plan:

- Livability—Promote livable communities;
- Mobility—Improve the mobility of people and freight;
- Efficiency—Maximize the efficiency of the existing and future transportation system;
- Accessibility—Improve accessibility to major employment and other regional activity centers;
- Reliability—Improve the reliability and safety of the transportation system;
- Sustainability—Minimize effects on the environment; and
- Equity—Ensure an equitable distribution of the benefits among various demographic and user groups. *(9)*

Freight is called out specifically in the "mobility" goal, but one could envision the movement of freight as having a part of each of the other six goals as well. An Atlanta, Georgia, regional freight study provides an example of a goals statement developed specifically for a freight planning study. The goals for this study were to:

- Create a level playing field for freight in the regional planning process;
- Address the differing regional and corridor needs of freight movement and activities;
- Minimize the cost and improve the reliability of goods movement within the region; and
- Improve goods movement in terms of ease, reliability, and transportation system related cost in the Atlanta Regional Commission planning area. *(10)*

As seen above, goals can be fairly general statements of desired outcomes. Objectives are more specific statements of what is to be achieved for each stated goal. For example, the San Diego Association of Governments (SANDAG) mobility goal had three specific objectives relating to how this goal was to be achieved:

- Tailor transportation modal improvements to reflect supporting land uses in major travel corridors.
- Priorities for regional transportation funding should go to early action program commitments and high-ranking projects and corridors.
- Minimize drive-alone travel by making it fast, convenient, and safe to carpool, vanpool, ride transit, walk, and bike, and improve goods movement. *(9)*

For the Atlanta study, the objectives included the following:

- Improve the movement of goods in the region by encouraging expedient and cooperative multimodal shipment of goods.
- Improve the physical characteristics of the transportation system for freight-related transportation between shipping and receiving points.
- Understand and address issues of concern to the freight community.

Performance measures are used as a means of monitoring what is happening on the transportation system. *(11)* As such, they are part of a statewide or metropolitan transportation planning process as a means of identifying potential problems in the transportation network. In most cases, a targeted set of performance measures focus on the performance characteristics of most importance to system operators and decision makers. Thus, one often finds measures relating to road congestion or travel delay, average speed, degree of accessibility to major retail and service markets, transit ridership, travel time reliability, bridge conditions, and safety. In many cases, freight movement is included inherently in such performance measures. For example, trucks are often caught in congestion as much as passenger cars are. In this instance, efforts to ameliorate congestion would benefit truck movements, as well as passenger flows. There are some examples, however, where freight-related performance measures have been explicitly defined as part of a planning process. Table 13-2 presents freight-related performance measures that were found as part of a national survey of planning practice. Note in this table that some measures are very specific to a particular terminal or freight facility and thus would not likely be part of a more general regional planning process.

13.4.3 Collecting Data and Analyzing Alternatives

13.4.3.1 Data

The greatest amount of time and effort in transportation planning is spent on data collection and analysis. This is the step of the planning process where alternatives are identified, analyzed, and refined or discarded depending on the

Table 13-2 Examples of freight-specific performance measures

Performance Category	Focus	Freight-Related Performance Measure
Accessibility	Business access to freight services	• Percentage of wholesale and retail sales in the significant economic centers served by unrestricted (10-ton) market artery routes • Percentage of manufacturing industries within 30 miles of interstate or four-lane highway
	Quality and quantity of freight services	• Number of shipping establishments per 1,000 businesses • Number of package express carriers • Capacity of package express carriers • Percentage of goods moved with option of more than one modal choice • Availability of real-time cargo information
	Roadway performance measures	• Average circuitry for trucks of selected origin-destination pattern • Number of truck-days of highway closure on major freight routes • Number of overload permits rejected due to structural capacity deficiency • Number of structures with vertical or horizontal clearance less than X feet • Bridge weight limits • Percentage of truck vehicle-miles of travel (VMT) or tonnage affected by weight restrictions or clearance on bridges • Percentage of truck highway bridges sufficient in load capacity (vertical and horizontal clearance) • Percentage of highway system with bridges that are structurally deficient or functionally obsolete • Sufficiency rating Percentage of bridges meeting federal sufficiency rating) • Geometrics of connector link
	Intermodal facility performance measures	• Average distance to intermodal terminals from different community shipping points • Number of intermodal facilities • Capacity of intermodal terminals • Average travel time between intermodal facility and rail • Degree of turning radius from major highway to intermodal facility • Number of twenty-foot equivalent (TEU) containers (or railroad cars) that can be stored in intermodal facility • Number of trucks that can be loaded with bulk material per hour of loading time • Types of modes handed • Freight dock availability • Track capacity (size and acreage) • Double stacking capacity or rating • Number of intermodal facilities that agency assists in development
	Port performance measures	• Number of ports with railroad connections • Lift capacity
Mobility	Roadway	• Delay per ton-mile traveled by mode • Ton-miles traveled by congestion level • Line-haul speed • Capacity restrictions • Miles of freight routes with adequate capacity • Percentage of lane miles that are truck priority or truck exclusions • Tonnage moved on various transportation components by mode • Facility usage by mode (volume/capacity) • Freight carrier or local shippers appraisal of quality of highway service in terms of travel time or speed, delay, circuitry, scheduling convenience • Truck VMT by light- duty, heavy-duty and through trips • Ton-miles of rail freight into/through metropolitan areas • Truck delivery and loading interference with street traffic

Table 13-2, *continued*

Performance Category	Focus	Freight-related Performance Measure
Mobility, *continued*	Intermodal	• Average transfer time/delays • Dwell time at intermodal facilities • Truck turn-around time at intermodal terminals • Average processing time for shipments at intermodal terminals • Delay of trucks at facility per VMT • Delay of trucks at facility per ton-mile • Frequency of delays at intermodal facilities • Customs delays • Tons of commodity undergoing intermodal transfer • Average travel time between intermodal facility and rail
	Other	• Average cost or speed for a sample of shipments • Traffic at border crossings • Number of dockage days at seaports

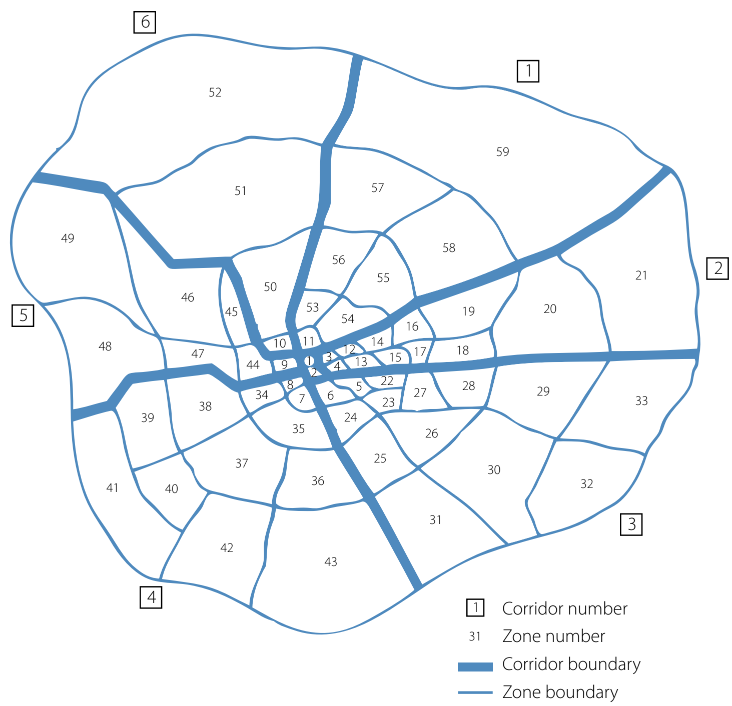
SOURCE: *A Guidebook for Performance-Based Transportation Planning.* (*11*)

overall goals of the study. Basic to any analysis process is having the data that describe the current situation and that can be used in the analysis to describe likely consequences of following one strategy versus another. The planning process has for years been dependent on a range of data and data collection techniques, aimed primarily at understanding traveler behavior, with little attention paid to freight-related data. *(12)* Thus, transportation planners have historically spent considerable time collecting data on household characteristics, employment statistics, traffic volumes, transit ridership, traveler and travel behavior characteristics, and network factors.

Although there has been a recent trend to collecting more disaggregate or individual traveler-level data, most transportation data have traditionally been collected and organized on the basis of geographic location or type of transportation facility. For example, every metropolitan area is divided into analysis units, often called traffic analysis zones (TAZs), which form the basis for the analysis of travel movements within, into, and out of the region. (See Figure 13-2.) Traffic analysis zones are usually defined based on several criteria: (a) achieving homogeneous socioeconomic characteristics for each zone's population; (b) minimizing the number of intrazonal trips; (c) recognizing physical, political, jurisdictional, and historical boundaries; (d) generating only connected zones and avoiding zones that are completely contained within another zone; (e) devising a zonal system in which the number of households, population, area, or trips generated and attracted are nearly equal in each zone; and (f) basing zonal boundaries on census zones.

Much of the data that are used for travel demand modeling and aggregated by TAZ come from either travel surveys conducted in the study area or from the US Census. Historically, the Census Bureau collected additional travel-related data on the so-called long form of the decennial census, which targeted one of six housing units in the nation. The major source of census

Figure 13-2 Zonal system for transportation planning



data for transportation planning in the future will be the American Community Survey (ACS), which has replaced the long form of the decennial census. The ACS is a continuous survey in that approximately 250,000 surveys will be sent each month to US households. The implication to transportation planning is that more timely data will now be available for use in the transportation planning process.

Although the zonal system depicted in Figure 13-2 has been devised primarily for the analysis of passenger transportation, these zones are often used when doing freight planning, often modified slightly to account for major freight-generating nodes. Freight-related transportation planning data generally involve obtaining information on the types and magnitudes of commodities shipped, modes of conveyance, origins and destinations, shipment and terminal travel times, loading and berthing requirements, daily and hourly variations in shipments, and frequency of shipments. Where trucks are involved, their number, type, weight, commodities carried, and use of roadways are important.

The freight data needs for transportation planning are shown in Table 13-3. The data are collected in various ways, including the following:

- Telephone interviews of shippers and carriers—Such interviews can collect useful information on the decision-making considerations for route selec-

Table 13-3 Freight data needs for transportation planning

Function	Data Needs	Support for Planning
Congestion Management	• Truck hours of travel • Average speed or travel rate • Added truck-hours due to delays • Truck transport cost per truck-mile • Added cost due to congestion • Transport time reliability • Types of trucks and commodities delayed • Energy consumption (truck-mile or ton-mile) • Emissions rates (truck-mile or ton-mile)	• Understand impact of congestion on goods movement • Understand contribution of trucks on urban congestion and air quality problems
Intermodal Access	• Volumes of trucks entering or exiting facility • Variability in demand for facility services • Congestion-related delays on access roads • Queuing delays related to capacity of facility • Accident rates on access roads • Travel time contours around facility • Number of people living/working within x miles of facility	• Identify land-side access improvement needs
Truck route designation and maintenance	• Truck traffic volumes • Origin/destination patterns • Truck size and weight data • Assess pavement damage and replacement needs	• Identify high-volume truck routes and corridors
Safety mitigation	• Accident rates • Rail-grade crossings • Low-clearance bridges • Steep grades	• Identify safety hazards and develop mitigation strategies
Economic development	• Truck volumes • Commodity movements • Origin/destination patterns • Shipping costs	• Assess economic benefits and costs of freight transportation investment projects

SOURCE: *A Guidebook for Performance-Based Transportation Planning.* (*11*)

tion, issues associated with the regional transportation system, origins and destinations of goods movement, and data on types of truck movements and commodities carried. Interviews tend to yield a high response rate.

- Intercept surveys—Truck operators can be interviewed at a cordon line around a study area, often as part of a comprehensive transportation planning study. The surveys should identify the volumes and types of commodities moving into and through an area, the destinations of these commodities, and the types of vehicles involved. Intercept interviews can also be conducted at truck weigh stations. If the weigh stations are located near the cordon line, there is usually space for trucks to pull out for interviews.
- Questionnaires—These can be distributed at for-hire truck terminals and followed up with in-depth interviews. The same procedures can be fol-

lowed for major rail, marine, or air cargo terminals. Interviews could obtain information such as the following:

- A detailed description of the routine operation of the terminal, including hours of operation, workflow, volume fluctuations, and types of commodities carried in the areas served.
- A description of operational characteristics of the terminal, including capacity, number and types of trucks and rail cars served, and special equipment used.
- The types of records maintained at the terminal that might be utilized in a comprehensive goods movement survey, including shipment patterns and commodity characteristics.
- Particular problems noted or experienced.
- Reaction to various alternative solutions.

• Global positioning system (GPS) based data collection—Recently, GPS technology has been used to improve the accuracy and amount of data collected in truck studies. In-vehicle devices can accurately combine time-coding and location data with user input about trip characteristics. All data collected by these units can then be easily input into geographic information system (GIS) maps, producing visual displays of route choices and travel patterns.

• Loading and unloading studies—Studies of loading deck operations are used to determine space requirements and geometric design criteria. These studies investigate occupancy and dwell times, often by land use type. The information provides a basis for establishing desirable on-street and off-street loading space.

• MPO freight advisory committees are one of the more innovative primary sources of freight data. As part of the normal organizational structure of the MPO, these advisory committees provide policy input into the planning process representing those issues of most concern to the freight sector. These committees have also helped in collecting the data needed for effective planning.

Similar in concept to transportation planning for passenger movement that relies on national census data or other large databases, freight-related transportation planning can also use national or regional databases to conduct transportation planning. Tables A-1 through A-5, which appear at the end of this chapter, list available data sources that could provide important information for a freight study. Users of such sources need to exercise caution when using this data by understanding the type of data that was collected, the survey methodology, and the possible application of such data in a transportation planning study.

Two of the most-used freight databases for freight-related transportation planning are the commodity flow survey (CFS) and a proprietary database called Transearch (IHS Global Insight). The commodity flow survey is undertaken by the Census Bureau every five years (the most recent ones being 1992, 1997, 2002, and 2007). This is a very valuable database because it is one of the few freight databases that provide information on commodity flows, rather than simply the movement of vehicles. *(13)*

13.4.3.2 Analysis

The analysis of transportation deficiencies and opportunities for improvement often relies on a variety of models and analysis tools. Analysis is the process of understanding the different aspects of a problem that will lead to possible solutions. In transportation planning, this often means estimating the future demand for a facility or system and the resulting performance given these expected demands. The interactions and interrelationships among all of the different variables that influence travel behavior and travel patterns are so complex that transportation planners often rely on models to predict the likely outcomes of changing any particular characteristic of the activity system or of the transportation network. Models are simplifications of reality—that is, they are designed to replicate as much as possible what is happening on the transportation system. However, in order to do so in a reasonably cost effective and timely fashion, most models are based on assumptions and data-based estimates of the behavioral relationships resulting in travel demand.

The types of analyses conducted for a particular study will depend on study goals and on the issues that have been identified during the planning effort. For example, in most freight planning studies, likely economic impacts are often one of the most important considerations for decision makers. Thus, the analysis of different alternatives would want to study the consequences of each alternative with respect to economic impact criteria. As noted in a report of the Transportation Research Board, the types of information that would be part of an economic impact assessment include the following:

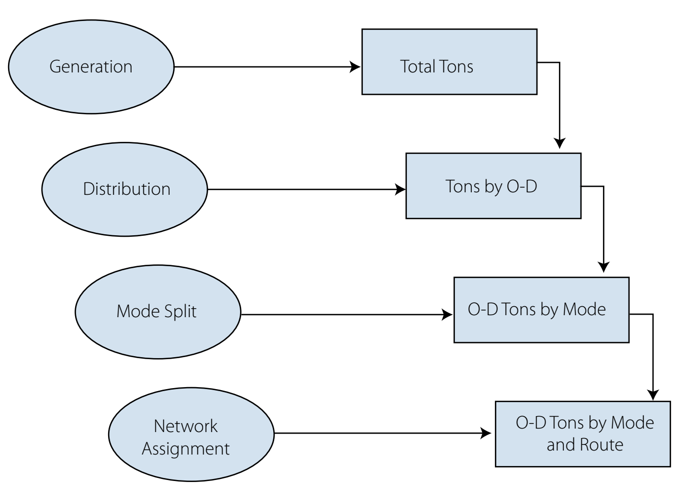
- National- and international-scale freight network capacity and level-of-service needs;
- Economic competitiveness, growth, productivity, and trade;
- Benefits to specific regions, modes, or industries; and
- Allocation of costs and benefits among affected parties to assess equitable funding. *(14)*

In order to analyze the performance of the transportation system given expected travel demands, it is necessary to model transportation networks. Most metropolitan areas have a transportation network coded into a computer software program. A network consists of two major elements: links that represent connections between two points (such as roads, transit services, pedestrian ways, etc.) and nodes, which represent connections to the network (such as transit stops or terminals or freeway ramps) or points on the network where a change of direction can occur (such as an intersection). Links have associated with them a link performance function that characterizes the performance of the link, such as travel time or delay, on the basis of travel volumes.

Passenger travel demand models can be generally divided into two categories. The first includes those models based on a four-step analysis process. The second category includes those techniques used to model trip makers' activities over a travel time period; this type of model is referred to as activity-based models. The four-step modeling approach consists of trip generation, trip distribution, mode choice, and trip assignment. Such models answer the questions: How many people will travel? What are the travel patterns for the study area? What travel modes are used? What trip paths will be followed through the transportation network? A similar set of questions could be asked and modeled for freight movement. (See Figure 13-3.)

The four-step process represents the most commonly used modeling approach for transportation planning in states and metropolitan areas. Where such network models are used to analyze both passenger and truck movements, truck flows are usually incorporated into the demand model with separate commercial vehicle or truck-specific generation, distribution, and assignment procedures. The trucks, or more accurately, the passenger car equivalents of the trucks, are assigned to the most efficient path through the network, taking into account road congestion and the desire to minimize travel time. It should be noted that this approach does not lend itself to examining other types of freight movement, such as that using rail, air, or inland water. In such cases, separate efforts are undertaken to determine how commodities will flow through the transportation system, and the results offered as an exogenous factor in the four-step modeling process.

Figure 13-3 The four-step analysis process for freight movements

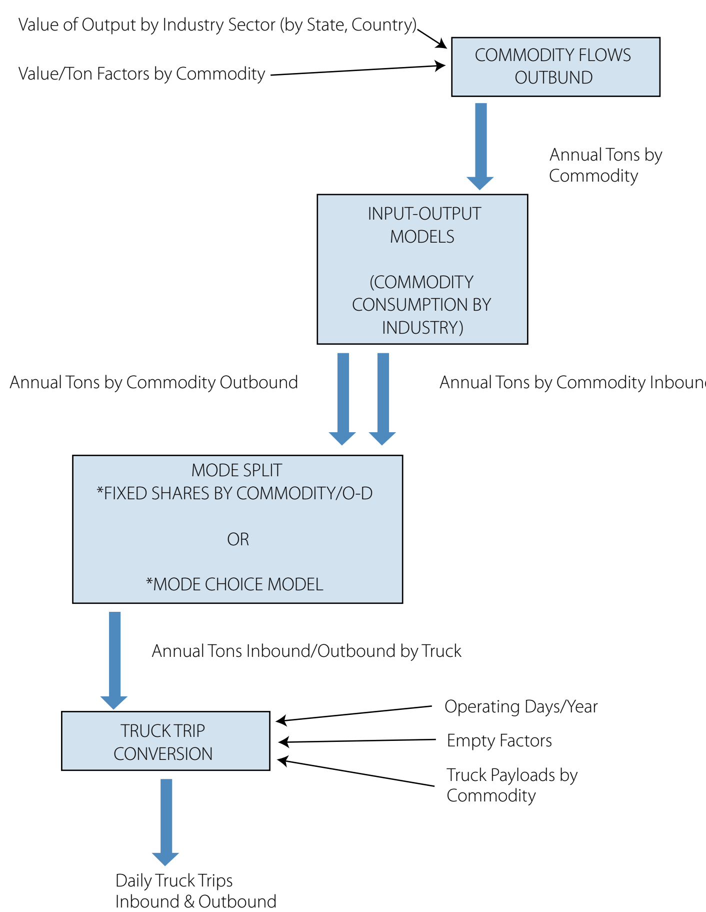


O-D: origin-destination

More sophisticated modeling approaches can be used to provide input into any one of the modeling steps of the four-step process, or in developing a freight-specific model itself. For example, transportation planners often use truck trip generation rates that relate the number of truck trips to some characteristic of the land use generating or attracting those trips (see Fischer and Han's work for an example of how truck-specific data is used to estimate truck trip generation [*15*]). This approach relies on counting the number of trucks accessing or leaving particular sites and then relating the truck trip rates to the land use (e.g., thousands of square feet of retail space). Figure 13-4 shows a more complex approach, yet one more appropriately based on economic factors, that could be used to replace the simple trip generation assumptions inherent in many of today's models (in this model construct, the number of truck trips would still have to be allocated to study area zones). Notice in Figure 13-4 that there is a mode split step that allows the analyst to determine commodity flows by mode of transport.

There are many references that discuss in detail the different types of freight models that are used in practice. It is beyond the scope of this chapter to review this information at any level of detail. Chapter 14 of this book provides a more focused discussion on freight modeling, as do several other sources. *(16, 17, 18)*

Figure 13-4 Determining the number of truck trips from commodity flow data



SOURCE: *Truck Trip Generation Data.* (*15*)

13.4.4 Evaluating Alternatives

The evaluation process synthesizes the information from the analysis of alternatives and presents this information in a way that shows the relative value of each. This information is used to determine what set of projects and strategies should be implemented given the amount of funding that is available, or in other words, which of the set of alternatives analyzed are most desirable? The challenge to the evaluation process is defining how value is to be measured, estimating the source and timing of the benefits and costs of the proposed actions, and comparing these benefits and costs to determine a level of effectiveness for each alternative.

The evaluation criteria that are part of this process relate to the overall goals and objectives of the planning study, and thus the types of information produced during the analysis stage of the planning process. No set of criteria is common to all planning studies. However, in general, the evaluation process attempts to answer the following questions:

Appropriateness

- What are the impacts and trade-offs associated with each alternative? Are they appropriate in light of the desired community goals?
- Do the objectives attained by the alternative reflect previously specified community goals and objectives?

Effectiveness

- Is the alternative likely to produce the desired results?
- To what extent are planning and community goals attained through the implementation of the alternative?
- Which of the set of alternatives is most cost effective?

Adequacy

- Does the alternative correspond to the scale of the problem and to the level of expectation of problem solution?
- Are there other alternatives that might be considered?

Efficiency

- Does the alternative provide sufficient benefits to justify the costs?
- In comparison with other alternatives, are the additional benefits provided (or foregone) worth the extra cost (or cost savings)?

Equity

- What is the distribution of benefits and costs among members of the community?
- Do any groups pay shares of the costs that are disproportionate to the benefits they receive?

Implementation Feasibility

- Will the funds be available to implement the alternative on schedule?
- Are there any administrative or legal barriers to alternative implementation?
- Does the organizational capability (e.g., staff and expertise) exist to implement the alternative?
- Are there groups that are likely to oppose the alternative?

Sensitivity Analysis

- How are the predicted impacts modified when analysis assumptions are changed?
- What is the likelihood of these changes occurring?

The Atlanta Regional Commission's recent freight planning study provides an example of the use of questions as the basis for evaluating different actions as part of a regional freight transportation planning effort. *(10)* This study's freight advisory committee helped the study team define the key criteria that were most important to regional decision makers. These criteria were transformed into the following evaluation questions.

- *Truck Diversion:* How much does the project or strategy shift freight from truck to rail and remove through truck traffic from the region's highway system?
- *Highway Congestion/Delay:* How much will the project or strategy reduce highway congestion and delay for both passenger and freight movement?
- *Rail Congestion/Delay:* How much will the project or strategy reduce rail congestion and delay for freight movement?
- *Travel Time/Reliability:* How much will the project or strategy improve travel time and reliability for both passenger and freight movement?
- *Freight Trip Times:* How much will the project or strategy improve trip time for freight movement?
- *Truck Traffic Peak/Off-Peak Shares:* How much will the project or strategy shift the share of truck traffic from peak to off-peak times?
- *Freight Vehicle-Miles of Travel:* How much will the project or strategy reduce regional truck vehicle-miles of travel?
- *Freight Vehicle-Hours of Travel:* How much will the project or strategy reduce regional truck vehicle-hours of travel?
- *Safety:* How much does the project or strategy reduce truck crashes and improve pedestrian safety along corridors?
- *Truck Emissions:* How much will the project or strategy reduce truck emissions?
- *Community Impacts:* How much will the project or strategy reduce community impacts associated with goods movement along transport corridors and freight intensive areas, including those in dense areas?
- *Land Use Impacts—Transport Corridors:* How much will the project or strategy reduce land use impacts associated with goods movement along transport corridors?

- *Land Use Impacts—Intermodal/Warehouse/Distribution Facilities:* How much will the project or strategy reduce land use impacts associated with goods movement between intermodal yards, warehouse, and distribution facilities?
- *Regional Economic Output/Competitiveness:* How much will the project or strategy improve the economic output and competitiveness of the region?
- *Jobs/Economic Opportunity:* How much will the project or strategy increase the number of jobs and economic opportunity associated with goods movement in the region, including those immediately in proximity to freight businesses?
- *Cost:* What is the overall cost of the project or strategy?

As noted in the previous section on analysis, many decision makers are particularly interested in the economic impacts of different alternatives. In such a case, economic impact evaluation might include information on the following:

- *Form of economic impact*—How the proposed project will reduce costs, improve productivity, or generate additional income or jobs;
- *Geography of affected markets*—How the effects will accrue at the local, regional, national, and international levels; and
- *Distribution of economic impacts*—How the effects will be distributed among key commodities and economic sectors. *(14)*

Answering some of these questions might require the use of economic impact models (e.g., supply chain models, regional economic simulation models, national productivity models, international trade models, or input/output models) that are beyond the capability of most state and metropolitan transportation planners. In such cases, professionals who specialize in economic impact analysis might have to be brought into the study.

One of the most important purposes (and challenges) of evaluation is to provide decision makers with some sense of which set of projects or alternatives is more desirable than others. Planners use different methods to provide some sense of relative project desirability, including goals achievement, numerical ratings, priority indices, multi-objective programming evaluation matrices, and economic evaluation techniques such as net present value, benefit/cost ratios, and rate of return. It is beyond the scope of this chapter to review the different types of comparative evaluation methods that can be used in the planning process. *(19)* Numerical ratings and priority indices will be discussed briefly in the next section, and Figure 13-5 illustrates a common evaluation approach that is often found in many transportation studies (in this case, from the Atlanta Regional Commission's regional freight mobility study).

Figure 13-5 Freight strategy evaluation matrix, Atlanta

Project Category	Truck Diversion	Highway Congestion	Rail Congestion	Travel Time Reliability	Freight Trip Times	Off-peak Shift	Freight Vehicle-Miles of Travel	Freight Vehicle-Hours of Travel	Safety	Emissions	Community Impacts	Land Use Corridors	Land Use Industrial Centers	Economic Competitiveness	Job Opportunities	Project Costs
	Evaluation Criteria															
Highway Capacity	●	●	◉	◉	●	◉	○	◉	◉	○	○	○	○	◉	○	●
Interchange Bottlenecks	○	●	○	◉	◉	○	○	◉	●	◉	○	○	○	○	○	●
Intermodal Connectors	○	○	○	○	○	○	○	○	○	○	◉	◉	◉	○	○	◉
Mainline Rail Capacity	●	◉	●	○	○	○	○	○	○	○	○	○	○	◉	○	●
Grade Separation	○	○	○	○	○	○	○	○	◉	○	●	○	○	○	○	●
ITS Technology	○	○	○	○	◉	○	○	○	○	○	○	○	○	○	○	○
Public-Sector Operations	○	○	○	○	◉	○	○	○	◉	○	○	○	○	○	○	○
Private-Sector Operations	○	◉	○	◉	◉	●	○	○	○	○	○	○	○	○	○	○
Institutional Changes	●	●	●	○	◉	○	○	◉	◉	○	○	●	●	●	◉	○
Safety	○	●	○	●	●	○	○	○	◉	○	○	○	○	◉	○	◉
Freight Land Preservation	○	◉	○	○	○	◉	◉	◉	○	◉	●	●	●	●	●	○
Improve Data & Analysis	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Regional Leadership	◉	◉	◉	○	◉	○	◉	◉	◉	◉	●	○	●	●	○	○
Public Awareness	○	○	○	○	○	○	○	○	◉	○	◉	◉	◉	○	○	○

● High Impact ◉ Medium Impact ○ Low Impact

13.4.5 Putting Together an Action Plan and Program

Once the planning process has produced all of the information that is needed and desired by decision makers, the action plan itself and/or an investment program must be developed. When freight considerations are part of a broader transportation planning process, the transportation plan and transportation improvement program will present all of the projects and strategies that are recommended for the study area. Freight and goods movement will usually be part of these more general recommendations, although in some cases, a chapter or section will be devoted to those actions that will benefit freight movement.

The prioritization criteria for developing a financially constrained investment program will reflect the variety of goals and objectives that were identified at the very beginning of the planning process. For example, the North Jersey Transportation Planning Authority created a prioritization scheme based on the allocation of a maximum 1,000 points to each project. The categories for points allocation included: environmental quality, system user benefits, repair/maintenance/safety/security benefits, economic development, system coordination/connectivity, and land use. Improvements to roads and bridges that would reduce congestion to the traveling public would also provide travel time benefits to truckers using the road system. Thus, many of the criteria that were used to prioritize projects in the region were relevant to projects that would also benefit freight movement. In addition, some of the 1,000 points could be allocated for impacts that were directly related to freight movements. For example, the following freight-specific criteria (and associated points) were part of this prioritization scheme:

- Will the project positively enhance the movement of freight? Maximum points: 36
  - If truck percentage is greater than the average for the road functional classification–36 points.
  - If the project improves access to rail yard, freight depot, or industrial park. Examples include increasing overpass clearance, providing access roadways for trucks, or improving nearby interchanges or intersections–18 points.

Another example of a freight-oriented prioritization scheme is found in the state of Washington. The Freight Mobility Strategic Investment Board of Washington State is responsible for one of the most comprehensive public freight investment programs in the United States. *(20)* This program allocates public funds to freight projects in the state that satisfy certain criteria. The projects are prioritized by allocating points in the following categories:

- Freight and Economic Value - 15 Maximum Points
  - Benefit mainline rail operations
    - ›› High—5 points
    - ›› Moderate—3 points
    - ›› Minimal—1 point
    - ›› Negligible—0 points
  - Access to key employment areas—0 to 5 points
  - Support faster train movements—0 to 5 points
- Environment—10 Maximum Points
  - Reduce vehicle emissions—0 to 5 points
  - 1.0 × delay in attainment area
    - ›› 1.5 × delay in nonattainment area
  - Reduce train whistle noise in crossing vicinity (number of sensitive receptor sites)—0 to 5 points
- Partnership—25 Maximum Points
  - Matching Funds (35% match is required) —20 maximum points
    - ›› Public-sector participation (1 point for every 4% of match after initial 20%)

    - ›› Private-sector participation (1 point for every 2% of match after initial 20%)
  - – Critical timing of partner investments—0 to 5 points
- Consistency with Regional and State Plans—5 Maximum Points
  - – Regional transportation plan—3 points
  - – State level transportation plan—2 points
  - – Not in regional or state transportation plan—0 points
- Cost—10 Maximum Points
  - – Cost effectiveness (reduced delay time/project cost)–0 to 7 points
  - – Degree to which least-cost alternatives are considered–0 to 3 points
- Special Issues—8 Maximum Points
  - – Address special or unique circumstances not otherwise addressed–0 to 8 points

In these types of schemes, those projects having the larger point scores are considered to be more important than those with lower scores. One can also apply category weights to add emphasis on different priority categories. In this case, the points assigned to each category would be multiplied by the respective category weight, summed across all categories, thus resulting in a priority index.

A freight action plan and/or strategy will often include more than just a list of freight-beneficial projects. For example, the New Jersey Statewide Comprehensive Freight Transportation Plan recommended the following:

- Establish a senior level body to promote logistics as a critical element of the state's economic prosperity.
- Implement an education, outreach, and local technical assistance program.
- Better integrate freight and economic development strategies to create enhanced value for communities through collaboration and communication.
- Facilitate warehouse development in the state.
- Support port authority development efforts, especially brownfield efforts.
- Give priority to underutilized and brownfield property development.
- Complete port access and intermodal access projects in the New Jersey DOT pipeline.
- Initiate a corridor assessment and project development process on priority freight corridors.
- Secure funding for development plan projects not currently funded.
- Support/promote port on-dock rail express rail improvements.
- Champion railroad projects that occur in other states that benefit New Jersey.
- Develop a coordinated mechanism for the planning and management of the rail system by engaging in (a) adopting standards for rail weight-carrying capacity and height/width dimensions, (b) identifying/prioritizing

at-grade crossing operational/safety improvements along key rail corridors, (c) creating a rail freight capacity-oriented project development process, and (d) aligning rail assistance program project priorities to broader system objectives.

- Continue to support port channel deepening and dredging efforts.
- Support the development of a rail/barge/coastal shipping distribution system into inland ports.
- Advance evaluation of sprint trains and rail shuttles within and outside the state.
- Support the Logistics Council's extended hours task force and assist in implementing recommendations and support efforts at marine terminals to extend gate hours.
- Work with the North Jersey Transportation Planning Authority to analyze the needs of the trucking industry for rest/service stops.
- Make it policy that heavier and wider trucks are not appropriate for New Jersey roadways, except in designated routes.
- Systematically examine the degree to which freight system needs are incorporated in the decision/prioritization tolls used by New Jersey DOT.
- Expand the agency efforts to advance the adoption and integration of freight intelligent transportation system technologies.
- Explore ways to incorporate funding considerations and partnerships early in the planning process.
- Continue efforts to conduct a five-year large truck monitoring program and a mechanism for sustained data and analysis coordination and sharing/develop improved highway freight analysis tools, data collection programs, and monitoring leading to the creation of a multimodal analysis tool.
- In partnership with federal and state agencies, evaluate measures that will enhance the tracking and control of hazardous materials movement.
- Monitor evolving federal security requirements and appropriately respond to the freight impacts associated with air cargo security requirements.

As seen in this list, the recommendations range from institutional mechanisms to enhance the consideration of freight issues in departmental processes to focusing investments on the warehousing and distribution center components of the state's logistics system. Many of the recommendations focus on securing the necessary funding for making the recommended improvements. It is not uncommon that many state and metropolitan transportation plans recommend different funding sources and innovative financing strategies. Given the importance of funding to the success of any freight-related plan, the next section will discuss different strategies for funding projects.

13.5 Public Funding and Financing of Freight Transportation Projects

The identification of transportation system improvements resulting in a more productive and efficient movement of people and goods is one of the most important products of a transportation planning process. However, no matter how useful identifying such improvements will be to a state or region, very little improvement will actually occur unless they can be implemented, which almost always requires some form of funding. Historically, public agencies have not provided public dollars to private firms to make improvements on their property. This was true primarily because it was felt there was very little public benefit associated with improving a rail line, a terminal, or even a port facility (where special port authorities are usually formed and have the ability to invest in such facilities under very specific state enabling legislation). This issue was at the heart of one of the most contentious debates in the early years of the founding of the United States, as national leaders argued whether it was appropriate (that is, did the Constitution allow) for federal money to be used to fund turnpikes and canals.

The road system, on which both passengers and freight movements occur, is a special case in that public dollars spent on the highway system should benefit those who use the system, and thus the basis for funding much of the road infrastructure in the United States includes a road user tax (the gas tax), other vehicle-related fees, and tolls. It should be noted that the public policy discussion of "who pays their fair share" of providing and maintaining the transportation system often enters into such issues as unaccounted for societal costs (and thus hidden public subsidies for road users) associated with such things as the costs relating to environmental degradation, public health, and use of nonrenewable natural resources (see, for example, the City of London's sustainable freight plan *[21]*). This particular issue, although important, will not be discussed in the following pages.

Chapter 15 provides a discussion of the different types of financing strategies that can be used to support investment in intermodal projects. It is important for the reader to understand that much of what is considered as part of the transportation planning process usually entails some form of public investment or public agency action. Private investment decisions relating to improvements in privately owned infrastructure, such as rail and trucking facilities, are made primarily on the basis of the expected return or profit on that investment. An investment might be made to expand into a new market, to retain market share in an existing market, or to make improvements that will reduce costs through enhanced productivity. The timing for this return and the required level of this return will vary by case, but the bottom line is that over time an investment should provide a profitable return to the company's owners or shareholders. Otherwise, that company will go out of business.

Public investment in transportation systems and services is usually based on the expectation that there will be benefits to the public or to society that justify the use of public funds. For example, much of the early debate on the funding of the interstate highway program in the United States rested on the argument that it would provide a means of rapid deployment of troops and material in the event of war—in other words, national defense. Other public investments are justified on the basis of economic growth, environmental quality, public health, and public safety. The federal-aid program for railroad grade crossings is an example of where Congress determined that it was in the public interest to provide funding to reduce the hazard to the traveling public posed by at-grade railroad crossings.

There has been growing interest in recent years in the types of projects that could be jointly undertaken by both public agencies and private investors. Called public-private partnerships, or PPPs, these projects are assumed to provide both public and private benefits and thus justify investment on the part of both parties. The key to negotiating PPP arrangements is determining what proportion of the costs should be borne by what party. An example of such a project might be improvements to rail or inland water facilities that would reduce the number of trucks on the road network and thus reduce congestion and associated environmental impacts. From a public perspective, congestion reduction and environmental impact mitigation would be worthy public investment, whereas facility improvements would benefit the private transport business.

13.5.1 The Difference Between Funding and Financing

The difference between transportation funding and finance is an important one when discussing the potential role of public support for projects that benefit freight movement. Financing is the strategy that is used to provide the amount of dollars that is necessary to build and/or operate a transportation facility or service. Thus, for example, a financing strategy might be borrowing dollars from the municipal bond market to finance the construction of a new road, or developing a public-private partnership in which some portion of the investment capital originates from a private investor and the remaining capital comes from a public agency. Funding, on the other hand, relates to the actual source of the dollars. Thus, a motor fuel gas tax is a funding source for a public agency transportation investment, as is a dedicated transportation sales tax.

The distinction between the two terms has become more pronounced in recent years as public agencies have begun to use financial strategies to provide the necessary resources to build and operate transportation facilities. It is important to recognize, however, that many of the financing strategies that require borrowing, such as low-interest loans or municipal market borrowing, require that there be a revenue stream available over the life of the borrowing (usually 25 to 40 years) that can be used to repay the capital and the accumulated interest. If a government agency guarantees bond payments with the budgetary resources of the government itself, the bonds are called general obligation bonds; if they are guaranteed with some dedicated revenue source, such as tolls or a sales tax, they are called revenue bonds.

13.5.2 Governmental Programs Supporting Freight Projects

The federal-aid transportation program is founded on legislatively mandated programs that support very specific transportation investment categories. For example, every five or six years, Congress passes legislation that authorizes the federal government to spend dollars on the US transportation system for specific purposes. The current legislation identifies programs such as the National Highway System, the Surface Transportation Program, the Interstate Maintenance Program, and the Congestion Mitigation and Air Quality Program, which enable federal dollars to support the types of projects authorized within each category. In addition, Congress passes legislation that focuses on very specific modal issues. The 2008 Rail Improvement Safety Act, for example, established funding programs and requirements for states to undertake planning and implementation efforts to improve passenger and freight rail in their state. It is beyond the scope of this chapter to discuss all of the federal programs that provide funding for transportation projects, and specifically the potential contributions toward freight-related projects (a Federal Highway Administration report provides an excellent overview of federal programs that are available and their limitations [*22*]). However, as has been stated previously, most of these federal programs are very limited in their ability to directly fund private freight projects.

Often, the source of most public funding for freight-related projects comes from state programs that target such projects primarily from the perspective of the economic benefits that are generated from the projects. Virginia has created the Virginia Rail Enhancement Fund and the Virginia Rail Industrial Access Program in order to support rail service within the state. Florida has some of the most multimodal programs in the country, with its Florida Seaport Transportation and Economic Development Funding and the Florida Strategic Intermodal System programs. Many of these programs are managed by the state DOT, but as was described earlier, some, such as the Washington State Freight Mobility Strategic Investment Board, have been established independent of state DOT oversight or management.

13.5.3 The Potential of Public-Private Partnerships

Where public and private benefits can be identified and where there is a willingness on the part of the parties involved to contribute to a particular project, a public private partnership could be a good strategy for supporting the project. As noted by the Federal Highway Administration, "Public-private partnerships refer to contractual agreements formed between a public agency and private entity that allow for greater private sector participation in the delivery of transportation projects." (*22,* p. 53) Such agreements could include the following:

- Design-bid-build: The design of a project is the responsibility of a public agency, and contractors bid on and build the project for the government agency.
- Private contract for services: The public agency transfers to a private entity the responsibility for services or functions that have traditionally been undertaken by the agency itself (e.g., road maintenance).
- Design-build: A private firm is contracted to both design and build a project, which is owned by the government. This is different from the first agreement above in that the design and the construction are undertaken by a single firm.
- Build-operate-transfer or design-build-operate-maintain: A private entity is responsible for building, operating and maintaining a facility, which is turned back to the public agency after some agreed period of time.
- Design-build-finance-operate: This is an agreement that goes one step further than the previous strategy in that the financing of a project is either wholly or partially transferred to a private entity. Some revenue stream must be available to pay the private investors for the capital they have invested in the project.
- Build-own-operate: Sometimes referred to as a concession agreement, this strategy allows a private entity to own a facility after it builds it under a concession agreement with the government. After a specified period of time, the facility usually reverts back to a public agency. The primary public agency role in this form of agreement is to specify performance and asset condition requirements that must be satisfied over the life of the concession.

Depending on the size and complexity of a project, the financing strategy might include a variety of funding sources and financing mechanisms. As one can imagine, putting together financing arrangements such as these often takes a considerable amount of time and negotiation.

13.5.4 The Future of Transportation Funding

In December 2007, the National Surface Transportation Policy and Revenue Study Commission reported on the current state of transportation policy in the United States and recommended that several steps be taken to streamline federal programs and stabilize transportation funding. *(23)* With respect to the future of federal transportation funding, the Commission concluded:

> Given the strong Federal interest in freight movement, Congress will need to make available a variety of funding sources to meet the needs of the Freight Transportation program. At the Federal level these include increased gas tax revenues, General Funds, and potentially a portion of Customs duties revenues and a Federal freight fee. It is also anticipated that tolling and PPPs would play an important role. A full range of financing options will be needed. *(23)*

The Commission assessed different funding strategies against what the Commission considered to be desirable strategy characteristics. Only five strategies are oriented to funding freight projects—impact fees, innovative finance, PPPs, container fees, and custom duties—and each is considered to be difficult to implement, except the use of custom's fees.

The VMT fee is considered by many as the likely source of funding in the long run given the market shift toward vehicles using hybrid and alternative fuels (which will result in a declining level of funding from petroleum-based motor vehicle taxes).

Providing transportation funding sufficient for maintaining current transportation infrastructure and putting in place capacity expansions that will be necessary to meet future demands is likely to be one of the most challenging public policy issues facing federal, state, and local officials in the future. Given the diversity of funding contexts at all levels of government, the most likely descriptor of future transportation funding programs is that they will be "menus" of different funding and financing strategies. In the near term—that is, over the next 20 to 25 years—the motor vehicle fuel tax will still likely be a, if not the, major source of funding for road projects. It also seems likely that states and metropolitan areas will continue to develop their own funding programs based on a variety of revenue sources, which could allow more flexibility in using such funds for freight-related projects if decision makers so choose.

13.6 Summary

This chapter described the transportation planning process and how freight concerns can fit into the different planning steps. In addition, examples were presented of freight-specific planning efforts that resulted in targeted recommendations on how to improve freight and goods movement in a state or metropolitan area. With projected increases in the levels of freight movements in the United States over the next several decades, it seems likely that the transportation system will be strained to handle the domestic and trade flows that are essential to keeping the country's economy healthy and productive. It thus becomes even more important that investment in the nation's transportation system consider the movement of freight in a systematic way.

One of the most significant challenges facing the transportation profession will be finding the funding that will be necessary to support this investment.

Over the past several years, governments at all levels have been exploring a variety of financing strategies that are part of the menu of strategies available for providing the desired levels of funding. Many of these strategies are public-private partnerships that encourage the participation of both public agencies and private investors in particular projects. Although such partnerships might make sense in certain circumstances, they are not likely to be the panacea for the funding challenges facing the US transportation system. With respect to freight projects, such strategies depend on clearly defining the public benefits and private gains that are associated with a project and dividing the project financing accordingly.

Transportation planning is undertaken in every urbanized area with a population greater than 50,000 and by every state. It is one of the most structured and systematic planning processes found in the United States, primarily due to federal regulations and guidance. Incorporating freight considerations into this planning process provides an opportunity to support the national, state, metropolitan, and local economies in ways that go beyond what has happened in prior years. With the importance of freight and international trade movements increasing in future years, this is an opportunity that should not be ignored.

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Table A-1 Modal network data

Source	Description/Attributes	Geographic Coverage	Agency
North American Transportation Atlas (NOTAD)	Geospatial information for transportation modal networks, intermodal terminals, and related attribute information	US totals, Canada, and Mexico	USDOT, Bureau of Transportation Statistics
National Transportation Atlas Databases (NTAD)	Most complete database source for highway network information outside Florida and for rail, water, and air networks for the zones inside and outside Florida	50 US states, District of Columbia, and Puerto Rico	USDOT, Bureau of Transportation Statistics
National Highway Planning Network, Year 2005	Highway link information in the United States (real-time information on vehicle movement and highway conditions)	Major US highways	USDOT, Federal Highway Administration (FHWA)
Strategic Highway Corridor Network (STRAHNET) and Connectors	Highway link information outside the Florida (real-time information on vehicle movement and highway conditions)	Major highway systems in 50 US states and District of Columbia	US Department of Defense, Department of Army, Military Traffic Management
Federal Railroad Administration (FRA) National Rail Planning Network	Digital representation of major continental US railway systems, including Canada and Mexico	50 US states, Canada, and Mexico	USDOT, Federal Railroad Administration (FRA)
Status of the Nation's Surface Transportation System: Condition and Performance	Highway, bridge, and transit operation and financial performance measures	National	USDOT, FHWA
Port Facilities Inventory	Detailed information on more than 4,000 major ocean and river port facilities (name, owner, operator, location, geographic boundaries, activity levels, wages, revenues, and number of employees)	Major US ocean and river port facilities	USDOT, Maritime Administration

SOURCE: *Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes.* NCHRP Report 594. Washington, DC: Transportation Research Board, 2007.

Table A-2 Commodity flow and volume data

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Transearch	All	Comprehensive market research data service for intercity traffic flows	Every 5 years, years ending in 3 and 8	Counties	Global Insight
Commodity Flow Survey (CFS)	All	Data on flow of goods and materials by mode of transport	Not specified Analysis Regions	US totals and 89 national transportation analysis regions	USDOT, Bureau of Trans-portation Statistics (BTS)
Freight Analysis Framework (FAF)	All	Estimates of commodity flows among states, regions, and major international gateways. The original version, FAF, provides estimates for 1998 and forecast for 2010 and 2020. The new version, FAF, provides estimates for 2002 and the most recent yearsplus forecast through 2035.	Not specified	States (FAF); 114 analysis regions (FAF)	FHWA, Office of Freight Management and Operations
The State Freight Transportation Profiles	All	Summaries of National Transportation Atlas Databases, Commodity Flow Survey, United States Waterway Data, and Railroad Accident/Incident Reporting System (RAIRS)	Not specified	50 states	USDOT, BTS
Current Industrial Reports	All	Current statistics on commodity production and shipments for approx imately 4,500 products	Annual	US totals	US Department of Commerce, Bureau of the Census
Shifts in Petroleum Transportation	All – Except Aviation	Movement, in ton-miles, of crude oil and petroleum products	Annual	50 states, District of Columbia, and Canada	Associated Oil Pipe Lines
Coal Distribution Data	All – Except Aviation	Information on coal distribution by origin, and method of transportation	Quarterly	Worldwide	US Department of Energy, Energy Information Administration
Highway Performance Monitoring System	Truck	National public road mileage on both a statewide and national basis	Annual	National, statewide, and urbanized areas	USDOT, FHWA
Truck Weight Study Data	Truck	Database contains information on weigh-in-motion and vehicle classification information collected at weigh sites	Not specified	US totals	USDOT, FHWA
Annual Vehicle Miles of travel and related Data	Truck	VMT estimates of current year and revised figures for previous years	Annual	US totals	USDOT, FHWA
Monthly Truck Tonnage Report	Truck	Information on tonnage moved by for-hire motor carriers	Yearly	US totals	American Trucking Associations

Continued

Table A-2, *continued*

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
TranStats	Truck	Data on truck movement, truck shipments that move across the Woodrow Wilson Bridge, Federal gas tax, and findings from Transportation Satellite Accounts	Varies	US totals	USDOT
Carload Waybill Sample	Rail	Rail shipment data such as origin and destination points, type of commodity, number of cars, tons, revenues, participating railroads, and interchange locations	Annual	US totals, BEA -to-BEA levels	Surface Transportation Board
Rail Waybill Database	Rail	Public-use aggregate non-confidential rail shipment data (freight volume and revenue data)	Not specified	US Class I railroads	USDOT, BTS
Weekly Railroad Traffic	Rail	Information on carloads by commodity and railroads plus intermodal traffic by railroad	Weekly	US rail carloads	Association of American Railroads
Domestic Waterborne Commerce of the United States	Seaport	Domestic waterborne commerce in short tons by commodity, vessel, operator, shipping and receiving dock, type of service, and trade agreement	Annual	US by ports	USDOT, Marine Administration
US Waterborne Exports and Outbound In transit Shipments	Seaport	Shipping weight and value by type of vessel service	Annual	Counties	US Department of Commerce, Bureau of Census
Port Import Export Reporting Service (PIERS)	Seaport	Comprehensive statistics on global cargo movements transiting seaports in the United States, Mexico, and South America to companies around the globe	Monthly	Global, including US seaports	Journal of Commerce Group .
Waterborne Tonnage by State	Seaport	Provides one page listing of the waterborne tonnage by States for a given year	Annual	US totals, US territories, 50 states, and District of Columbia	US Department of Defense, US Army Corps of Engineers
Origin and Destination of Waterborne Commerce of the United States, Public Domain	Seaport	Aggregate information on waterborne commodity movements between 26 geographical regions in the United States	Yearly	US totals, US territories	US Department of Defense, US Army Corps of Engineers

Continued

Table A-2, *continued*

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Airport Activity Statistics	Airport	Volume of revenue passengers, freight express, and mail traffic	Annual	US totals, state, and city	USDOT, BTS
Terminal Area Forecast	Airport	Air cargo volumes by commodity type	Not Specified	Select airports in the United States, including those with FAA control towers and/or receiving commercial service	USDOT, Federal Aviation Administration (FAA)
Federal Aviation Administration (FAA) Aviation Forecasts Fiscal Years 2006–2017	Airport	Air cargo historical and forecast volumes by commodity type those with FAA control towers	Not Specified	Select airports in the United States, including and/or receiving commercial service	USDOT, FAA
North American Airport Traffic Report. Airport Council International—North America Traffic Report	Airport	Airport activity statistics in terms of passenger and cargo operations	Not Applicable	130 North American airports	Airports Council International, North America

SOURCE: *Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes.* NCHRP Report 594. Washington, DC: Transportation Research Board, 2007.

Table A-3 Freight industry data

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Transportation Annual Survey	All – Except Aviation	Data on total operating revenue, and total operating expenses that include annual payroll and employee benefits, commodities carried, end-of-year inventory or revenue generating equipment, and type of carrier	Yearly	US totals	US Department of Commerce, Bureau of the Census
Motor Carrier Financial and Operating Information Program	Truck	Annual and quarterly survey of motor carriers (name, owner, operator, location, geographic boundaries, number of employees, wages, and revenues)	Quarterly and annually	National	Federal Highway Administration, Office of Motor Carriers
Trucking Activity Report (TRAC)	Truck	Benchmarking statistics for both truckload and less-than-truckload carriers	Monthly	US totals	American Trucking Associations
Vehicle Inventory and Use Survey (VIUS)	Truck	Physical and operational characteristics on the Nation's vehicle population	Varies	US totals, 50 states, District of Columbia	US Department of Commerce, Bureau of the Census
America's private Carriers—Who are These Guys	Truck	Charts and analysis information on private carrier segment of trucking industry	Annual	U.S totals	Transportation Technical Services (TTS)
Canadian Motor Carrier Directory	Truck	Survey of trucking firms in Canada (name, owner, location, geographic boundaries, activity levels, wages, revenues, and number of employees)	Not Specified	Canada	Transportation Technical Services (TTS)
Mexican Motor Carrier Directory	Truck	Survey of trucking firms in Mexico (name, owner, location, geographic boundaries, activity levels, wages, revenues, and number of employees)	Not Specified	Mexico	Transportation Technical Services (TTS)
Transportation Technical Services (TTS) Blue Book of Trucking Companies	Truck	Motor Carrier data including income, operating expense, labor, units, output, assets, and liabilities Private fleet not included	Annual	US totals, Canada	Transportation Technical Services (TTS)
Standard Trucking and Transportation Statistics (STATS)	Truck	Comprehensive overview of trucking industry (name, owner, operator, locations, geographic boundaries, activity levels, wages, revenues, and number of employees)	Annual	US totals	American Trucking Associations

Continued

Table A-3, *continued*

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
The Private Fleet Directory	Truck	Comprehensive overview of private firms with 10 or more trucks or tractors (name, owner, operator, locations, geographic boundaries, activity levels, wages, revenues, and number of employees)	Annual	US totals	Transportation Technical Services (TTS)
Trucking in Canada	Truck	Comprehensive overview of the Canadian trucking industry, both for-hire and owner-operations	Annual	Canada, provinces/ territories	Statistics Canada

Table A-4 Trade data

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
US Merchandise Trade	All	Tables on merchandise exports general imports, and imports for consumption	Annual	US Customs districts, world area by countries of origin/destination	US Department of Commerce, Bureau of the Census
US Exports of Merchandise	All	Year-to-date exports commodity information by district	Annual	US Customs districts of exportation	US Department of Commerce, Bureau of the Census
US Imports of Merchandise	All	Detailed general imports and imports for consumption data	Annual	US Customs districts of exportation	US Department of Commerce, Bureau of the Census
US Exports of Domestic and Foreign Merchandise	All	Exports by all modes to outside of the United States	Annual	US Customs districts of exportation	US Department of Commerce, Bureau of the Census
US General Imports and Impacts for Consumption	All	General imports and imports for consumption data	Annual	US Customs districts of exportation	US Department of Commerce, Census
Transshipment via Canada	All	Dollar value and estimated waterborne tonnage for United States exports and imports transshipped through Canada	Annual	US totals, Canada	Association of American Railroads
US General Imports and Imports for Consumption	All	Net quantity and value of imports for consumption and general imports	Annual	US Customs districts of entry and unloading and country of origin	US Department of Commerce, Bureau of the Census

Table A-4, *continued*

Source	Modes	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Transborder Surface Freight Data	All – except aviation	Annual tonnage and value data by commodity type and by surface mode of transportation	Monthly	US , Canada, and Mexico totals	US Department of Commerce, Bureau of the Census, Foreign Trade Division

SOURCE: *Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes.* NCHRP Report 594. Washington, DC: Transportation Research Board, 2007.

Table A-5 Socioeconomic and industry data

Source	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Regional Economic Information System	Base economic information for the US region outside of Florida, including population, employment by SIC code, housing construction, tourism, and sales by business group data	Every 10 years ending in 0	US totals, states, Basic Economic Analysis regions, MSAs, and counties	US Department of Commerce, Bureau of Economic Analysis) (BEA)
Statistical Abstract of the United States	National-level overviews of Freight Statistics, including operation cost, fuel consumption, employment, and revenue data	Annual	US totals, states, cities, metropolitan areas	US Census Bureau, Data User Service Division
Census Transportation Planning Package (CTTP)	Base year populations and households for analysis zones outside of Florida	Every 10 years ending in 0	US totals, state, county; places with more than 2,500 people	US Census Bureau
County Business Patterns	SIC employment data	Annual	US totals, state, and county	US Census Bureau
National Income and Product Account(NIPA)	Consumption information in US	Annual	US totals	US Department of Commerce, BEA
BEA Regional Projections to 2045	National Projections of employment by industry data	Annual	US totals, state	US Department of Commerce, BEA
Annual Surveys of Manufacturers	Additional employment data and value of goods shipped by type of goods	Annual	US totals	US Census Bureau, Manufacturing and Construction
Annual Surveys of Manufacturers	Additional employment data and value of goods shipped by type of goods	Annual	Canada, the providence and territories	Statistics Canada, Labor Division
Survey of Employment, Payroll and Hours	Employment data for eastern and western Canadian regions	No specific pattern	Canada	Statistics Canada, Census Operations Division, Census of Population

Table A-5, *continued*

Source	Description/Attributes	Cycle Update	Geographic Coverage	Agency
Covered employment and wages (ES-202) Programs	General employment data (number of employees, revenues, and wages by employment types	Annual	US totals, state, and county	Department of Labor, Bureau of Labor Statistics (BLS)
Current Employment Statistics	General employment data (number of employees, revenues, and wages by employment type)	Annual	US total, less details for states	US Department of Labor, BLS
Census Manufactures	Employment and manufacturing industries statistics as well as quantity and value of material consumed and products shipped	Every 5 years ending in 2 and 7	US total, state, and local geography	US Census Bureau
Info USA	Employment by industry using refined SIC codes as well as NAICS codes	Weekly	US totals, state, districts, and counties	Info USA
Consumer Expenditure	American household expenditures, income, and family characteristics	Weekly, and per metropolitan areas	US totals, four Census quarter	US Department of Labor, BLS regions, 26 selected

SOURCE: *Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes*. NCHRP Report 594. Washington, DC: Transportation Research Board, 2007.

14

Modeling Freight Flows

Frank Southworth

14.1 Introduction

Modeling freight flows, whether the intention is to simulate current goods movement patterns or to forecast future ones, presents a number of technical challenges. Some of these stem from the complex nature of the interactions that take place between freight shippers, carriers, receivers, and brokers. Other challenges are the direct result of data limitations that continue to plague this area of analysis. With government forecasts predicting high levels of freight traffic growth well into the next two decades, public agencies are concerned about the costs of building and maintaining new freight infrastructures and finding ways to cope with a steady rise in traffic congestion. At the same time, within the private sector the information technology revolution has helped businesses to identify a wider range of product delivery options and encouraged the use of many long-distance trips, including multinational product supply chains. This has led many shippers to place a greater reliance on transportation as a means of keeping their overall logistics costs down.

Understanding and quantifying the complex nature of cause and effect in such a dynamic business environment presents technical challenges. The search for greater understanding of, as well as accuracy in, freight activity forecasts has led to the application of an expanding set of mathematical and statistical methods, including both time-series and cross-sectional approaches. This chapter describes the principal freight flow estimation and forecasting techniques currently in use and the contexts in which each is usually applied. Example equations are provided for the most common estimation methods, and references are provided to many recent and well-documented applications.

Throughout the chapter, *freight flow model* refers to a method for simulating the amount of freight being shipped over a given time period between two or more places. These flows result because demands are made by businesses for raw, intermediate, or finished products that need to be shipped some distance from specific geographic locations. Flows are measured in a variety of ways, including tons shipped, number of container loads required, and the dollar value of goods being traded per day, month, quarter, season, or year. Depending on the issue being studied, these flows are broken down for operational, planning, or policy analysis according to mode of transport, source-market (origin-destination) pairing, types of commodities shipped, routes traveled, and shipment frequency. Shipment frequency may be paired with data on shipment size, and modes may be broken down into submodes or into specific vehicle and vessel types (vehicle configurations), depending on the need for detail.

The choice of modeling technique is very much context sensitive, depending on both the geographic and the temporal scope of a study, the level of detail and accuracy required of the forecasts, and, of course, on the specific study objectives (cost-effectiveness, project feasibility and selection, environmental impact assessment, etc.). It also depends a great deal on available data sources, which in turn tend to be heavily constrained by the temporal and geographic context of a particular study. Where the geographic context is effectively implicit, such as the study of a specific cargo terminal's throughput potential, then a time-series analysis of the historic trend in freight activity is often the expedient choice. Where the spatially explicit treatment of different, and typically competing commodity sources, markets, transportation modes or routes is involved, then recourse has traditionally been made to cross-sectional data sources. This is done in order to capture the full range of options available to freight shippers and receivers. In practice, and increasingly, both time-series and cross-sectional data play their part in the more comprehensive regional transportation studies.

The level of geographic detail required of freight flow models varies a good deal, from highly localized flows between production and consumption or storage facilities (e.g., mine to power plant) to flows between pairs of cities, states, or nations. Where flows between large numbers of origins and destinations are involved, such as those required by metropolitan, statewide, and increasingly multistate and national planning organizations, the resulting origin-destination (O-D) flow matrices need to be tied to a suitable level of zonal geography. These matrices can become quite large, involving hundreds of traffic analysis zones (TAZs), with further breakdowns in the resulting flows matrix by commodity class and mode of transport. Depending on study resources and purpose, the level of detail applied to the commodity class breakdown similarly varies a good deal, from something as specific as winter wheat to something as general as grain.

To understand and quantify the causes of variability in flow volumes between places and over time requires information on underlying demographic, economic, pricing, regulatory, and transportation infrastructure supply factors, as well as data on shipper, carrier, and broker views of the available transportation options. A challenge for all freight flow forecasting models has been to obtaining sufficiently detailed data on the nature of the flows themselves, as well as on the values of these location-specific explanatory variables, for a representative set of O-D movements.

The planning horizon to which a freight model is applied also plays an important role in the type of model selected. Broader regional studies carried out by metropolitan, statewide, and federal transportation planning agencies favor forecasts covering 5, 10, or more years into the future (50 or more years, where the life cycle costs of major investments in regional transportation infrastructures are being considered, such as US Army Corps of Engineers studies looking at inland waterway lock replacements). Shorter range forecasts, updated on an annual basis, are often more appropriate for location-specific, operationally oriented studies, such as studies of a seaport terminal's daily traffic arrival and departure activity. Where time-series data on historical flow volumes exist for such facilities, it has been possible to develop models that predict the daily, weekly, and monthly trends in freight shipment volumes, as well as to develop forecasts of longer run, multiyear trends in aggregate freight activity.

A growing interest in freight flow modeling has led to a steady stream of articles reviewing the freight modeling literature and specifically freight demand models. *(1–10)* Drawing on these review materials and many other individual studies, the rest of this chapter is organized as follows. Section 14.2 provides an overview of the principal modeling options. In particular, models are classified as being either aggregate flow models that are resolved at a level of geographic and temporal detail of direct value to engineering, planning, and policy studies; or as disaggregate, and typically respondent survey-based, models that have evolved as a means of bringing a more in-depth understanding of causality into the flow simulation and forecasting process. Section 14.3 describes how these different modeling approaches have been applied in five common geographic contexts: (i) models that estimate the volume of freight generated by and attracted to specific geographic locations and high volume freight processing facilities, (ii) freight flow modeling within metropolitan planning regions, (iii) statewide commodity flows and their associated freight movements, (iv) fully national as well as interregional freight flow models, and (v) models of international freight flows. Section 14.4 summarizes past and ongoing model developments.

14.2 Aggregate and Disaggregate Flow Models

Two quite different approaches to collecting and using data for public sector freight analysis have become popular. These are usually referred to in travel demand literature (on passenger as well as freight flows) as aggregate versus disaggregate demand models. In practice, the more sophisticated freight modeling frameworks incorporate both types of analysis. The key traits of each style of modeling are summarized below.

14.2.1 Aggregate Zone-Based Flow Models

14.2.1.1 Trip-Based and Commodity-Based Models

Aggregate freight flow models are built to provide flow estimates at a level of spatial resolution suitable for planning studies, and as such are based heavily on the use of existing government datasets. These datasets are either already tied to a specific set of TAZs, or they can be easily broken down or aggregated to fit them. Examples are the use of TAZs based on census block groups, tracts, or zip code areas for metropolitan planning, or the use of US counties as the basis for assigning flow originations (Os) and destinations (Ds) for statewide planning. Generating flow predictions between these Os and Ds then requires additional data on explanatory variables at the same level of spatial aggregation, such as annual economic activity (in dollars, tons, employment levels, disposable incomes, etc.) at each O and D, as well as O-D travel times, freight rates, and other dollar valued transportation costs. This aggregate, TAZ-based modeling has in turn evolved along two particular lines of development referred to in the literature as

- Vehicular trip-based models and
- Economic activity-based commodity flow models.

The trip-based approach is grounded in transportation engineering and planning studies and begins by estimating the number of vehicle or vessel trips we can expect from each of a region's TAZs, then fits additional models to distribute these trips across modes, destinations and, where required, across specific transportation routes. The second approach begins with freight movements as the expressions of commodity trades, which are in turn the result of industrial and commercial activity within regional economies, and from which we can then estimate, if desired, the number of vehicles and vessels involved, using suitable dollar-to-ton and ton-to-average vehicle load conversion factors.

14.2.1.2 Multistep Planning Model Frameworks

Both trip-based and commodity-based approaches fit into the sequential, four-step (traffic generation-distribution-mode split and route assignment) approach used by most metropolitan and regional transportation planning agencies for the past half century. (See Chapter 13.) This process, shown in Figure 14-1, is the same framework that is commonly used to estimate and forecast daily passenger flow volumes and assign them to routes within a region's highway and transit networks. Where freight flows are concerned the procedures shown in Figure 14-1 can be represented as follows:[1]

Freight Generation: $O_i = F(\underline{X}_i)$ and Attraction: $D_j = F(\underline{X}_j)$ (1a)

Freight Distribution (Flow): $\underline{T}_{ij} = F(\underline{O}_i, \underline{D}_j, \underline{c}_{ij})$ (1b)

Mode Split: $T_{ijk} = F(\underline{T}_{ij}, \underline{G}_i, \underline{G}_j, \underline{c}_{ijk})$ (1c)

Traffic (Route) Assignment; $\underline{T}_{ijkr} = F(\underline{T}_{ijk}, \underline{c}_{ijkr}, \underline{g}_{ijkr})$ (1d)

where F( ) means "a function of" and where both here and throughout this chapter i = a freight shipment's origin location (facility, traffic analysis zone), j = a shipment's destination, $\underline{O}_i$ = a vector of freight originating volumes (i = 1 2, . . . I), $\underline{D}_j$ = a vector of freight destination or delivery volumes (j = 1,2, . . . J), T = a per unit time-based measure of freight flow volume and where $\underline{T}_{ijkr}$,for example, refers to the volume of freight shipped from i to j by mode k and route r, c = transportation costs, and $c_{ijkr}$for example, refers to the cost of transporting a unit of freight from i to j by mode k on route r. Finally, $\underline{X}_i$,$\underline{X}_j$,$\underline{G}_i$ and $\underline{G}_j$ refer to vectors and g_{ijk}r to a matrix of explanatory variables associated with specific steps in the flow estimation process.

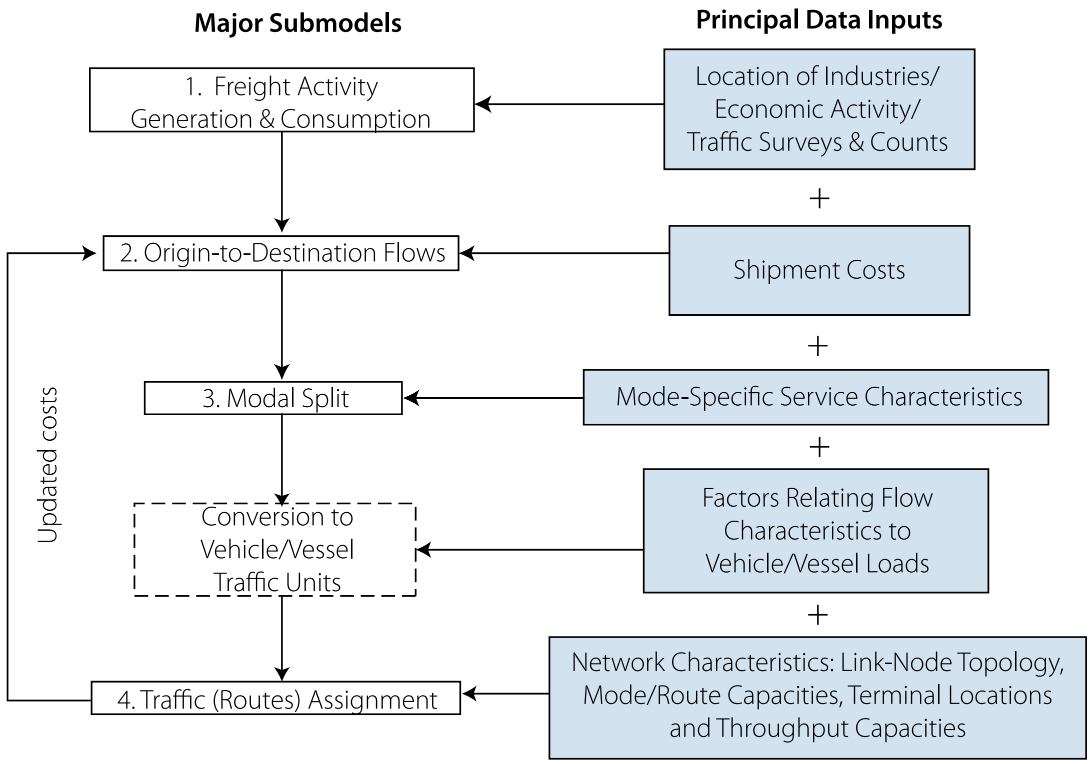
The freight flow model at the heart of this sequential flow estimation process is the freight distribution model. The most popular approach to date has been to estimate O-D flows based on some form of "gravity model" of spatial interaction. *(11)* A variety of gravity models have been calibrated to observed flow data for this purpose. Most, however, can be represented by the following equation, applied either to total freight moved or to the O-D movements of a specific commodity class:

$$T_{ij} = \gamma 0 * O_i^{\gamma 1} * D_j^{\gamma 2} * F(\gamma 3 * c_{ij}) \quad (2)$$

where the function F( ) to a specific form of "distance decay" effect, such as $c_{ij}^{-\gamma 3}$ after the initial idea of a gravity model or $\exp(-\gamma 3 * c_{ij})$ following the literature on entropy-maximization popularized by Wilson. *(12)* The O_i term here may be an estimate of total daily or annual tons shipped or the number of vehicles shipping out of traffic analysis zone i. Similarly, D_j is an aggregate estimate of the freight entering TAZ j. Both of these trip ends are often themselves estimated by a regression or other model (see Section 14.3.2) based on measures of economic activity. Solving for, or calibrating, equation (2) consists of finding the set of model parameters γ0 to γ3 that best fit the observed flows. This can be done by applying ordinary least squares regression to the natural

1 Underlined variables denote vectors.

➤ **Figure 14-1** Three-, four-, and five-step freight planning model frameworks



logarithm of the flows. More commonly, the various parameters in equation (2) are calibrated to match a matrix of observed O-D flows using gradient search algorithms tied to maximum likelihood estimation methods and custom-built computer codes. Movement costs, c_{ij}, may be represented by a freight rate, f, an in-transit departure-to-delivery time, t, as well as other cost-impacting measures, such as on-time delivery performance, or by a weighted composite of these and other situation-specific terms, i.e.,

$$c_{ij} = \alpha_0 + \alpha_1 * f_{ij} + \alpha_2 * t_{ij} + \ldots.. \quad (3)$$

A common strategy for obtaining an appropriate set of values for the parameters α_0, α_1, and α_2 is to get them from a disaggregate choice based analysis of individual shipper or receiver responses to a suitably representative set of shipment options, using survey data collected within the region (i.e., from the disaggregate demand modeling approach described in section 14.2.2.)

The sequential nature of the estimation and calibration process shown in Figure 14-1 reflects the difficulty past studies have had in obtaining good estimates of either passenger or freight flows from single equation, direct demand specifications. However, as is brought out below, developments in both simulation and econometric analysis have begun to suggest not only different formulations of each of the traditional submodels but also alternative analysis frameworks within which to apply them. Finally, the flow estimation process shown in Figure 14-1 is also meant to be iterative, with transport costs derived in the traffic route assignment stage being fed back to the trip distribution and mode selection models. This is an important step where such costs reflect the significant influence of network congestion on either the selection of modes or source-market pairings. This is often the case, especially where these same highways, waterways, railways, and airways are also moving high volumes of passenger traffic. Properly applied, this iterative process leads to a balance between estimated flows and their associated costs. This idea of a flow-cost balance, or equilibrium, is at the heart of much of the freight flow modeling literature, reflecting its close ties to the literature on spatial economics.

14.2.2 Disaggregate, Survey Response Based Flow Models

14.2.2.1 Utility Maximizing Logit Models

A weakness of the aggregate, TAZ-based flow models is the limited number of potentially important causal factors they can capture within the estimation process, and for which traditionally collected government data are not available. This can limit their value to policy studies. This has led to models that are instead calibrated to data collected from individual respondents—that is, the responses of representatives of shipper, for-hire carrier, and freight receiver and freight broker companies, as well as responses provided by operators (e.g., truck drivers) captured through vehicle intercept surveys.

The theoretical basis for such models is usually that of individual shipper or receiver utility maximization. Let U_h refer to the utility gained by an individual freight shipper or receiver from choice of transportation alternative h, then the probability of this shipper/receiver selecting alternative h, over all other available alternatives, h′ in the set h′=1,2, . . . h . . . H, can be stated as:

$$P(h) = P(U_h > U_h{}', \text{ for all } h' \text{ in } H) \tag{4}$$

The most popular form of disaggregate demand model is McFadden's (*13*) discrete choice multinomial logit (MNL), where

$$P(h) = \exp(U_h) \,/\, \Sigma_{h'=1,2,..H}\ \exp(U_{h'}) \tag{5}$$

and where Uh is typically a linear weighted combination of the utility (or in cost terms the disutility) of traveling by option h—i.e.,

$$U_h = \Sigma_{q=1...Q}\ \theta_q * Uq_h + \epsilon_h \tag{6}$$

for q = 1,2 . . . Q explanatory variables, and where ϵ_h = the model's random and unobserved error terms (and whose distribution determines the nature of the demand function). Model calibration consists of estimating the best fitting values for the parameters or variable weights $\{\theta_q\}$. In estimating destination choice, for example, the utility function U_h in equation (6) typically contains both positive aspects of market utility, such as market size, and negative aspects of utility, such as freight rates.

Since the introduction of MNL models in the early 1970s, a number of advances have been made in both discrete choice model formulations and in the identification and formulation of the freight agent utility functions contained within them. Ways that have been found to improve the explanatory power and (it is hoped) the forecasting accuracy of disaggregate demand models include (a) a considerable expansion in the number and type of explanatory variables used to explain the alternatives selection process, (b) the development of alternative forms of computationally tractable econometric demand models, and (c) an increasingly sophisticated market segmentation of either respondent (i.e., freight agent) or shipment types prior to demand model calibration.

14.2.2.2 Flow Affecting Explanatory Variables

With their ability to include a much wider range of explanatory variables based on in-depth respondent interviews, the latest disaggregate demand models can offer insight to the underlying causes of the freight flow patterns. They are especially useful for capturing the price elasticity of demand for freight services, while controlling for a range of otherwise difficult to capture exogenous effects. Over the past three decades, the number of explanatory factors used in such models expanded considerably as new data collection methods became available. Generally, the types of data collected can be put into two categories:

- Data on the behavioral responses of freight agents (shippers, receivers, carriers, brokers) to questions addressed through revealed or stated preferences surveys; and
- Data on company-level supply chain logistics, including data on inventory, transportation, and other logistical costs, as well as data on the nature of outsourcing of transportation services to for-hire carriers, either directly or via third party logistics (3PL) agents, or via other forms of freight brokerage firms.

Freight rates can capture a good deal of this variability in the cost imposed on shippers or receivers. However, survey responses and empirical modeling indicate that time-based reliability and other quality of service factors play an additional and important role in mode/supplier selection.

The mode choice question has been the most studied aspect of disaggregate freight demand modeling to date. Whatever the discrete demand model is used, it is now well understood that (a) level of service characteristics such as service reliability are often as or more important than freight rate, and (b) a mode's level of service characteristics are themselves only one of a number of issues affecting the mode selection process, which can depend on a potentially large number of often interrelated factors. These include

- the physical characteristics of the product (product weight, volume, density, value, packaging, safe handling needs, perishability, and shelf life);
- the shipment's characteristics (frequency, timing, and speed/urgency of delivery, shipment size and length of haul, and whether domestic or international);
- the shipping (or receiving) company's characteristics (firm size, organization hierarchy, the nature of outsourcing and supply chain operations, and company use of information technology such as Internet, intranets, vehicle and container electronic data identification tags);
- the shipper-receiver relationship (the customer as shipper or receiver; deliveries based on short run or spot contracts versus long-term delivery contracts; direct contracting versus use of 3PL or other freight broker);
- transportation's role in shipping company operations (the nature of the company's transportation assets, notably the use of company owned versus for-hire carriage; the relationship of transportation costs to total logistics costs; the size, knowledge, and responsibility level of transportation staff);
- level of service characteristics (freight rate, in-transit time or speed, on-time reliability, safety/security/damage record, service/schedule flexibility, service availability at short notice, control over delivery time, available cargo handling options, and use of intermodal transfer facilities); and
- governmental regulations that affect product movements (domestic and international laws and practices). *(14-17)*

Some of these variables have measurable effects in the short term (e.g., a commodity's physical characteristics and current O-D flow pattern); while others have more difficult to assess longer-term effects (e.g., company size, size of the company's vehicle fleet, warehouse locations). All tend to be situation specific, presenting a challenge for not only model development but also subsequent transferability to other "like" situations.

14.2.2.3 Alternative Discrete Choice Model Formulations

A number of alternatives to the MNL formulation have been developed and applied empirically. For the most part, these models address statistical issues associated with the choice among two or more transport alternatives that are highly and similarly correlated across the set of commonly used explanatory variables. This includes the nested logit model *(15)*, the C-logit and F-logit models *(18)*, and the random effects mixed logit model. *(19)* Each approach offers improvements and greater flexibility in the treatment of transportation choices. All offer ways to get around the assumption of independently and identically distributed (IID) randomness associated with each choice alternative, an assumption that renders the MNL computationally tractable in multiple-choice situations, but subjects it to the condition that cross-substitutions among pairs of alternatives (e.g., rail versus truck, truck versus barge) are unaffected by the presence of a third or subsequent alternative. The nested (hierarchical, or tree) logit gets around this independence from irrelevant alternatives (IIA) property by partitioning the choice set into two or more levels, capturing as much similarity across alternatives as possible within each level, then recombining levels by averaging results from lower back into upper level nests. *(20)* This is done using logsum terms (also called inclusive value or expected maximum utility terms). For example, Jiang et al. *(15)* use a nested logit model to estimate the modal split between long-haul rail, truck, and truck-rail intermodal freight transportation in France. They distinguish first of all between private and for-hire transport as an upper level choice or "nest" and model the choice between rail, road, and intermodal options within the for-hire nest only. (Figure 14-2) Here we can represent the choice between road, rail, and road-rail intermodal within the for-hire carriage option by the usual multinomial logit equation (5), given above. We can then compute the expected maximum utility, U, from this choice set as the logsum, Z, of that model's denominator as

$$Z_{k/\text{for-hire}} = \ln \left[\sum_{k'=1,2,..K} \exp(-U_{k'}) \right] \quad (7)$$

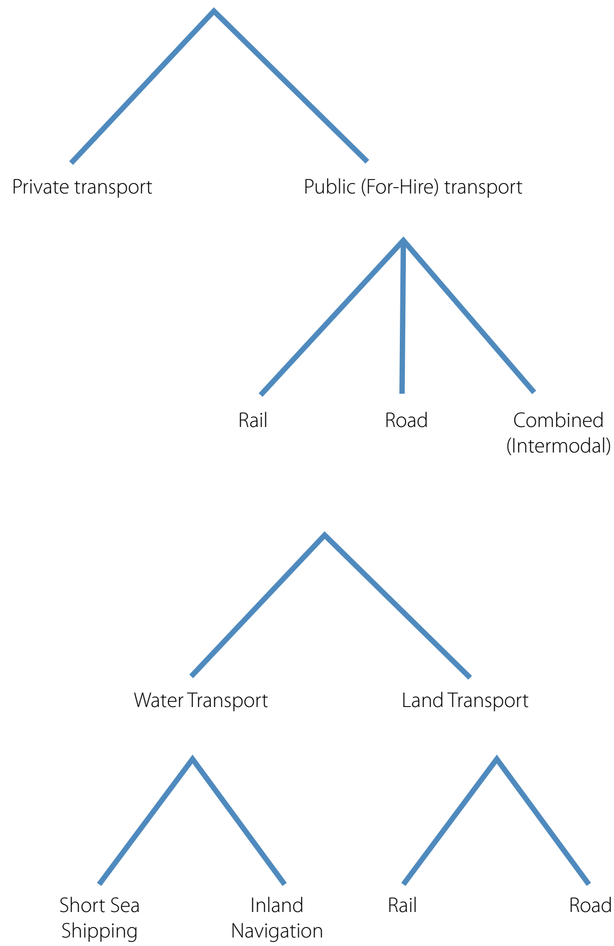
and then use this result to determine the business choice, b, between for-hire carriage and private carriage as

$$P(\text{for-hire}) = \exp(-U_{\text{for-hire}} + Z_{k/\text{for-hire}} * \mu_b) / [\exp(U_{\text{private}}) + \exp(-U_{\text{for-hire}} + Z_{k/\text{for-hire}} * \mu_b)] \quad (8)$$

for a suitably calibrated scaling parameter μb. Figure 14-2 also shows a second nesting example for creating a choice tree based on similarities between different modal options. *(17)*

Similarly, the choices between shipment frequency, modes, destinations, and routes could also be solved as a series of four nested logits, data permitting. However, rather than preserve the traditional choice sequence, other studies have instead sought to combine two or more of these different choice dimensions. For example, in response to a significant change in commodity prices or transportation costs, a shipper (receiver) may in the short term choose to shift modes, shift markets (sources), or simply cut back on the volume of freight produced (purchased). Train and Wilson *(21, 22)* address this situation with a tobit model, which they apply to a survey of grain shipper responses to a possible loss of river access. Here the value of a stated preference approach to data collection proves valuable, as it allows the analyst to elicit responses to "what would you do if" types of questions that demonstrate the often cross-cutting nature of choices, such as the situation in which some shippers will choose to ship less of a product in response to a change in transport costs, while other shippers may decide to switch mode and/or market. Recognizing the joint nature of many decisions, modified logits have also been applied to combined mode and shipment size choice *(23)* and to combined shipment size and truck vehicle class decision making. *(24)* Model selection here is often a trade-off between the use of statistically valid and computationally tractable mathematical model formulations and the ability to capture as realistically as possible the nature of the decision-making context.

Figure 14-2 Examples of nested logit model structures



14.2.2.4 Flow Aggregation Methods

To be useful to many planning studies, disaggregate models require a suitable means of expanding their resulting flow estimates to TAZ or other regional totals. At least three approaches have been used for this purpose:

1) variants on the naive averaging method, which bases its aggregate estimates on the average values of each of the explanatory variables (freight costs, etc.) while using carefully selected market segmentation to reduce within segment variation and the aggregation bias associated with nonlinear models. (*15*)

2) the use of cost or utility function parameter values from disaggregate choice models such as equation (6) to weight the average region-to-region transport costs used to calibrate aggregate freight flow models. (*25*)

3) the use of microsimulation models that construct individual shipments based on pseudo-random selections from the probability of choice distributions implied by discrete choice models, including the generation of shipment size and frequency, vehicle class, mode, route, and/or destination choices. (*26–28*)

Models based on microsimulation represent a strong candidate for future freight flow modeling. The approach offers a means of overcoming the limitations of more traditional mathematical forms while (and this is arguably its major current contribution) making the most of existing data sources. The idea here is a conceptually simple one of trying to simulate individual freight movements from the bottom up, then adding them together to get planning level flow data. The most common method for associating specific attribute values with a given shipment is some form of Monte Carlo pseudo-random selection procedure. The microsimulation model creates a synthetic population, in the sense of a simulated 100% sample of shipments. When the simulator is asked to select the shipment's frequency, mode, route, destination, or shipment size, it draws values from a set of probabilities that have been created using, for example, a logit choice model. The result is a representative set of shipments that are otherwise far too costly to piece together from data collection alone. Microsimulation is especially useful for generating large numbers of daily multistop pickup and delivery truck tours based on the output from logit regressions or other discrete choice models that are used to select such attributes as the next stop's trip purpose, location, and departure time interval. When linked to the latest developments in "agent-based modeling," the approach can also be designed to emulate the actions of individual freight agents (shippers, carriers, warehousers, brokers) in order to generate the many commodity, mode, route, vehicle, container, source, and destination specific shipments these actors play a part in creating. *(8)*

14.3 Modeling Freight Flows in Different Geographic Contexts

14.3.1 Flow Modeling Application Areas

In this section, freight flow models are reviewed for the following commonly applied spatial and planning agency contexts:

- Location-specific freight activity,
- Metropolitan (urbanized area) flows,
- Statewide freight flows,
- National and interregional flows, and
- International flows.

While a certain similarity exists across all applications, each of these contexts creates unique model requirements and has produced context-specific model developments. These different model applications can also be viewed as a spatial hierarchy of freight models, but one in which model results may flow in both directions. In particular, flow estimates for high-volume freight activity centers are now often fed into urban and statewide modeling frameworks, while statewide models benefit from the use of nationally modeled, broad regional freight activity control totals. National models, in turn, benefit from international freight/trade flow modeling of imports and exports. To date, however, these five model application areas have functioned largely independently of each other.

14.3.2 Location-Specific Flow Generation/Attraction Models

The flow estimation process shown in Figure 14-1 begins by estimating the volume of freight both generated by origin and attracted to destination in each TAZ in the region. If a trip-based modeling approach is followed, as is common when estimating intra-urban or intrametropolitan freight (principally truck) flows, three types of data are often used, sometimes in combination: traffic cordon counts, vehicle roadside interviews, and shipper, warehouser, or carrier establishment surveys. *(29)* Three options for predicting zone-specific freight activity levels from this data are also in common use:

- Empirically derived average trip rates,
- Cross-sectional regressions, and
- Time-series models of traffic growth.

Listings of average truck trip rates are available for many different commodity classes, as well as for different types of truck transport if the analyst is willing to accept the results of past studies from other regions. *(1, 29)* These rates are variously measured in daily commercial truck trips per acre, per square foot of a specific class of land use, per employee, and per dollar earned within a given industrial sector. Reliance on the transferability of these trip generation/attraction rates is questionable. A preferred alternative is to use locally collected data and develop regression models to link daily trip volumes to a range of socioeconomic, land use or transportation supply variables. For example, the following multiple linear regression equation was used to forecast daily truck trip activity internal to TAZs in the southeastern Wisconsin region, centered on Milwaukee: *(30)*

$$TTRP = 96.650 + 0.123HH + 0.304\ REMP + 0.196OTHEMP \qquad (9)$$

where

TTRP = number of commercial truck trip ends,

HH = number of households,

REMP = number of retail employees, and

OTHEMP = number of other (nonretail) employees.

Fischer and Han *(29)* provide a comprehensive review of this literature for truck trips, including truck class-specific regressions and supporting data sources. Having tried a variety of single and multiple regression models with mixed results, including truck trips regressed against terminal area and storage area, Cartwright et al. *(31)* chose another approach. They instead developed a multistep spreadsheet model of truck trips based on a detailed terminal operations-throughput model fitted to data on the number of gate specific transactions, terminal throughput, and traffic counts. The authors report that the modeled trip rates were then used to generate peak hour, peak period and daily truck-class specific trip tables for the port's facilities, subsequently treating individual terminals as TAZs in the Southern California Association of Governments' regional transportation model.

The use of time-series data offers a natural third option for forecasting facility-specific freight generations and attractions, and notably the volumes of freight moving into and out of high volume special freight generators, such as seaports, airports, international border crossings, truck villages, and other large freight terminal complexes. Where seaports and other intermodal terminals are concerned, transportation planners have also made use of data on the number of vessel or train arrivals to translate the expected volume of freight to be moved into truckloads. For example, the Delaware Valley Regional Planning Commission (referenced in *29*) used the following simple linear regression models for seaport and rail terminal trips, respectively:

$$O_i = \text{Truck trips/day out of seaport i} = (2.02 * \text{Ship Arrivals/Year}) - 20 \quad (10a)$$

$$O_i = \text{Truck trips/day out of terminal i} = (0.0095 * \text{Rail Cars/Year}) + 24 \quad (10b)$$

See also Holguin-Veras et al. *(32)* for rates and regressions based on a nationwide survey of 21 marine container terminals.

Time-series analysis can also offer a relatively parsimonious data requirement if past trends in freight movement activity are easily tied to just one or two explanatory variables. This appears often to be the case, at least where short- to medium-term (up to five-year) forecasts are concerned. Past studies offer a variety of methods to choose from, including simple growth factor methods, multiple regressions *(33, 34)*, exponential smoothing *(35)*, artificial neural network *(36–40)*, multivariate autoregressive *(41)*, Box-Jenkins autoregressive and moving average *(42, 43)*, space-time autoregressive moving average *(44, 45)* and space-time multinomial probit models. *(46)* No approach dominates the literature, and a number of these studies offer comparisons between two or more of these methodological alternatives. Choice of model appears to depend to a large extent on analyst preference and data availability. Of note, some recent studies devoted to forecasting the volumes of freight passing through seaports have opted to replace regression-based freight generation and attraction models, including lagged time-series based regressions, with better fitting models based on artificial neural networks (ANNs), and in particular on the feed-forward back propagation neural network (BP-NN) method. In these models the inputs are a lagged time series of data on past seaport traffic throughputs and/or economic activity levels, and the outputs are a set of observed truck trip volumes by time period. *(38–40)*

14.3.3 Freight Flows Models for Urban Areas

Urban areas, and in particular larger metropolitan areas, are home to many different types of freight flow. These include:

- Internal-external movements: high volume flows that have only one end located within the region and the other located some distance away, often in another urban area. This includes shipments that are part of an intermodal supply chain in which cargo passes in and out of large freight generators, such as a seaport. These may be truck, rail, barge, air, short sea shipping, or oceangoing vessel trips.
- Internal truck flows: including single stop, alternately fully loaded then empty round trips (e.g., dump trucks serving building sites), and a variety of fully or partially loaded, multistop pickup and drop tours by single unit trucks and commercial vans.
- External-external movements: through trips that typically use the high capacity links in the local transportation network to begin and end outside the urban area. These may be long-haul truck, rail, or barge trips.

These different types of urban freight movement exhibit different functional relationships with an area's underlying employment and land use patterns and therefore require different types of demand models in order to simulate them. This also means that if all of the major components of metropolitan freight movement are to be represented within a single regional transportation plan, then a mix of modeling techniques is often needed.

To date, most urban freight flow models have focused on truck movements, avoiding the mode choice issue. Instead, they use a three-step vehicle trip-based freight generation-distribution-assignment model (Figure 14-1), employing either regression-based or empirically averaged truck trip rates and network-based transportation times and other freight movement costs to fit gravity trip distribution models. Fitting such models to observed truck movements has proved to be a challenge, however, in large part because of the limited amount of directly observed data on truck trip origins and destinations. One solution has been to use a combination of data on either modeled or observed truck freight origins and destinations, supplemented by data on terminal gate- and/or highway link-specific truck traffic counts, to solve what is sometime termed a *link-OD* model. The purpose of such models is to produce an estimated set of O-D flows that is consistent with a set of known and network link-specific traffic counts. While model formulations are very much application specific, most link-OD models of interest can be expressed as special cases of the following general optimization model:

$$\text{Minimize } F(T,T') + F(V,V') \qquad (11)$$

subject to

$$V = M(T) \tag{12}$$

where

$\underline{T}$ = a vector of "observed" O-D freight flows,

$\underline{V}$ = an "observed" set of network link or terminal specific freight traffic volume or throughput measures,

$\underline{T}'$, $\underline{V}'$ = the model estimated versions of $\underline{T}$ and $\underline{V}$, and

$M(\underline{T})$ = a "mapping" between $\underline{V}$ and $\underline{T}$.

$F(\underline{T,T'})$ and $F(\underline{V,V'})$ refer to measures of the differences in the values of the observed versus model estimated O-D flows and site specific traffic volume counts, respectively. List and Turnquist *(47)* provide one of the best known examples applied to the estimation of O-D truck movements within New York City. Rios et al. *(48)* provide an example that includes flows with trip ends in different urban areas, including longer distance rail, as well as truck routes. (See also *49*.)

For congestion analysis or road damage assessment purposes, the truck flows resulting from these spatial interaction models are then assigned to specific capacity constrained paths through the regional highway network. This means assigning trucks to routes that also carry automobile traffic, as well as a growing number of lightweight commercial service vehicles (couriers, pizza delivery vehicles, household and office equipment repair crews, etc.) This is accomplished by first converting truck volumes into daily congestion impacting passenger car equivalents (PCEs). Thus a large combination truck-trailer may be represented as three PCEs in order to relate a network link's auto-equivalent flow to its auto-equivalent design capacity. And if a commodity-based spatial interaction model has been used, then dollars traded need to be put into tons shipped, which in turn need to be translated into an appropriate number of vehicle PCEs.

Where choice of vehicle type is a significant issue, as in the case of pavement damage assessment studies, a vehicle class model may also be added to the process. (Figure 14-1) In effect, this means fitting a vehicle choice model for each commodity class (ideally including a mixed freight class). This can be done in the simplest case by using suitable average dollar-per-ton conversion ratios, and then taking into account typical vehicle ton-based load factors, including allowance for empty vehicle repositioning legs or backhauls. The ability to account for empty trips is an important consideration here if accurate truck traffic volume counts are a requirement of the flow modeling process. *(49)* This means either collecting local data specifically for this purpose, or using average values from a source such as the US Commodity Flow Survey for dollar-to-ton conversions, then using a source such as the US Vehicle Inventory and Use Survey to relate truck types to average loads. This also means having a way to identify which classes of truck are being used to move different types of urban freight, which in turn requires data that match truck type to commodity class. A popular source of information for this purpose at a crude level of commodity breakdown is again the US Vehicle Inventory and Use Survey. Given locally collected vehicle intercept or establishment surveyed data, disaggregate forms of demand model can also be used to estimate these vehicle class shares.

The most popular forms of urban, mixed (passenger and freight) traffic assignment models currently in use are variations on Wardrop's *(50)* "user optimal" travel time minimization problem, which can be stated as

$$\text{Minimize } v_a \qquad \Sigma_a \int_0^{f_a} C_a(x)dx \qquad (13)$$

subject to:

$$v_a = \Sigma_i \Sigma_j \Sigma^r \delta_a^r Q_{ij}^r \qquad \text{for all links, a, in the network} \qquad (14)$$

$$\Sigma_r Q_{ij}^r = T_{ij} \qquad \text{for all } i = 1,2,...I, \text{ and all } j = 1,2,...J \qquad (15)$$

$$v_a \geq 0 \qquad \text{for all a links} \qquad (16)$$

$$Q_{ij}^r \geq 0 \qquad \text{for all ij pairs} \qquad (17)$$

where v_a = the number of vehicles (PCEs) flowing over network link a; Ca (v_a) = the travel cost on link a, at flow volume v; Q_{ij}^r = the volume of origin i to destination j traffic assigned to route r; Qij = the total traffic volume between i to j summed over all r routes; and δ_a^r = 1 if link 'a' belongs to route r and = 0 if otherwise.

Solution of equations (13)–(17) produces an equilibrium between route-specific vehicular flow volumes and network travel times, on the assumption that shippers (as well as personal trip-makers) act in such a way that they each minimize their own transportation costs. To get this result we must solve simultaneously for link volumes, v_a, and i-to-j flow volumes, Q_{ij}. In doing so, equation (14) ensures that the volume of traffic assigned to network link a equals the flows on all r paths through that link, while equation (15) ensures that flows on i-to-j paths sum to the total i-to-j flows. Equations (16) and (17) ensure nonnegative flows. Model validation is then usually a process of comparing the resulting route-specific model estimated truck volumes with cordon based, terminal gate based, and other link-specific and vehicle class-sensitive traffic counts, collected using in–the-pavement loop detectors and other forms of intelligent vehicle counting devices.

Alternative demand models as well as alternative model frameworks, have been proposed as replacements for this traditional *generation-distribution-traffic route assignment* urban freight planning model. For the most part, these are efforts to link freight flows more closely to the underlying demands for commodity movements, as well as to capture the influence of business logistics practices on company-selected transportation choices. The greatest challenge facing such efforts at the present time lies in getting the most out of limited size shipper and receiver establishment surveys, limited size truck intercept or motor carriers surveys, and a limited number of network link-based truck traffic counts. A number of studies have used shipper establishment survey data to support disaggregate discrete choice demand models, with Monte Carlo simulation and other microsimulation modeling techniques offering a means of expanding the results of these model calibration exercises to regional flow totals. One practical improvement offered by these models is the ability to simulate explicitly the thousands of daily multistop pickup and drop tours used by many of the smaller types of urban delivery and commercial service trucks. In North America the data collection and modeling techniques reported by Hunt and colleagues for cities in Alberta, Canada, *(26, 27)* provide promising applications.

A second and immediately practical modeling improvement is to identify flows passing through large cargo handling facilities by creating a freight warehousing or freight distribution land use category, then treating these truck flows within a separate demand model. This includes the truck freight associated with large *freight villages* and other regional freight processing depots. Such depots exist within a number of countries to consolidate and break up large volumes of cargoes originating in, or destined for, metro areas. (This recognition of the important role played by regional seaports and airports as well as other types of *special* freight generators also sets the stage for using the sort of time-series based models of facility-specific freight traffic growth described in Section 14.3.2 as inputs to the area-wide modeling of freight movements). At least one commercially available freight modeling package in the United States, called Cube Cargo *(52)*, incorporates truck tour logic, as well as warehousing land use considerations, into its urban transportation planning software.

Moving still further from the traditional model, completely new urban freight demand forecasting frameworks that make use of both tour formation logic and microsimulation are being proposed on a number of continents. *(53–57)* Fully realized, urban truck tour-based flow models capturing the wide range of possible commodity pickup and delivery service options remain to be developed, however, as do their datasets.

14.3.4 Statewide Freight Flow Models

14.3.4.1 Multistep Freight Planning Models

Beagan et al. and Holguin-Veras et al. (*1, 4*) provide reviews of US freight flow modeling as practiced by a number of state transportation agencies within the United States. A TRB toolkit *(58)* provides statewide freight forecasting along with descriptions of a number of case studies sponsored by state departments of transportation, using variations on, and in some cases combinations of, the modeling methods described in this section. Unlike most current urban freight models, this includes modeling the choice between the different long-haul modes of transport: truck, rail, water and (less so to date) pipeline and air freight. Both trip-based and commodity-based flow models are used, with the commodity-based approach proving increasingly popular. This is due in part to the absence of detailed and consistently collected freight traffic generation or attraction data for many parts of the same state. In contrast, an input-output based approach to commodity flow modeling (see below) can bring a much needed consistency to the data preparation and subsequent modeling process. A commodity-based modeling approach also offers a direct connection to not only the types of freight being moved, but also to government supported industry-to-commodity conversion tables, the industries that create these freight demands in the first place—industries that get a lot of attention when it comes to tracking their business activities for taxation and other government administrative purposes.

14.3.4.2 Commodity Flow Models

The commodity based approach to freight flow prediction is based on Leontief's *(59)* interindustry input-output (I-O) framework. It requires access to an appropriate I-O model for a state's entire economy. Such I-O models are usually represented succinctly in matrix form by the following equation:

$$\underline{X} = \underline{A}\underline{X} + \underline{Y} \tag{18}$$

where $\underline{X}$ is an N by 1 vector of industry outputs, $\underline{Y}$ is an N by 1 vector of final demands (made up of personal or household consumption, government spending, and net exports) and $\underline{A}$ is an (N * N) regional input-output coefficients matrix, with a typical element given as

$$a_{mn} = x_{mn} / X_m \tag{19}$$

where X_m is the output of industry m and x_{mn} is the output of industry m sold to industry n. The inter-industry demand for a particular industry m's output is estimated as

$$X_m = \sum_{n=1},N\ (a_{mn} * X_n) + Y_m \tag{20}$$

so that final demand is given as

$$Y_m = X_m - \sum_{n=1,N} (a_{mn} * X_n) \tag{21}$$

A common application of these relationships is an assessment of the economic impact on each industrial sector's level of production due to a change in a region's final demands, $\{\underline{Y}_m\}$. Returning to matrix notation, this can be represented as

$$\Delta\underline{X} = (\underline{I}\text{-}\underline{A})^{-1} * \Delta\underline{Y} \tag{22}$$

where $(\underline{I}-\underline{A})^{-1}$ is the Leontief inverse, with identity matrix $\underline{I}$.

Under this framework a change in the final demand for an industry's product initiates additional production in goods and services by its supplying industries, which in turn sets off a chain reaction that results in additional goods and services being required across a number of different industries, a process known as the multiplier effect. The beauty of the approach is its ability to translate these effects across all of a region's industries in a completely balanced way. Note that to obtain the volumes of a specific *commodity* produced or consumed in a given region requires a translation from an industry-based to a commodity-based set of inputs and outputs. In the United States, the Bureau of Economic Analysis provides a set of national I-O tables. This includes a *make table,* in which the rows represent industries and the columns display the commodities that each industry produces, and a *use table,* in which the rows represent the commodities or products and the columns display the industries and final consumers that utilize them. Methods for creating regional industry-to-commodity tables also exist. *(60)*

Where such an I-O based approach is being used as the basis for estimating the dollar value of commodities produced and consumed, freight flows are assumed to occur where the within-region supply of a commodity proves insufficient (or not sufficiently cost competitive) to meet the local demand. Building on ideas developed in the early 1950s through the early 1970s, and in particular the work by Isard *(61)* and Wilson *(12)*, a variety of spatial interaction models have been tied to Leontief's I-O framework. One such model is the "doubly constrained" form as follows:

$$T_{ijm} = A_{im} * B_{jm} * V_{im} * D_{jm} * F(c_{ijm}) \qquad (23)$$

where T_{ijm} = volume of commodity m shipped from i to j, where i and j are two traffic zones in the set of 1,2,,,i, . . . j, . . . Z such zones; O_{im} = volume of freight shipped from location (traffic zone) i $[= \sum_{n=1,N} X_{imn}]$; D_{jm} = volume of freight received at location j $[= \sum_{n=1,N} X_{jmn}]$; c_{ijm} = the cost of shipping a unit of m from i to j , and $F(c_{ijm})$ = a distance-dependent function of transportation costs. The A_{im} and B_{jm} terms in equation (23) represent two sets of matrix "balancing factors," given as:

$$A_{im} = 1 / [\sum_{j=1,Z} B_{jm} * D_{jm} * F(c_{ijm})] \qquad \text{for all } i \qquad (24)$$

and

$$B_{jm} = 1 / [\sum_{i=1,Z} A_{im} * O_{im} * F(c_{ijm})] \qquad \text{for all } j \qquad (25)$$

which upon iteration to balance ensure that

$$\sum_{J=1,Z} T_{ijm} = O_{im} \qquad \text{for all } i \qquad (26)$$

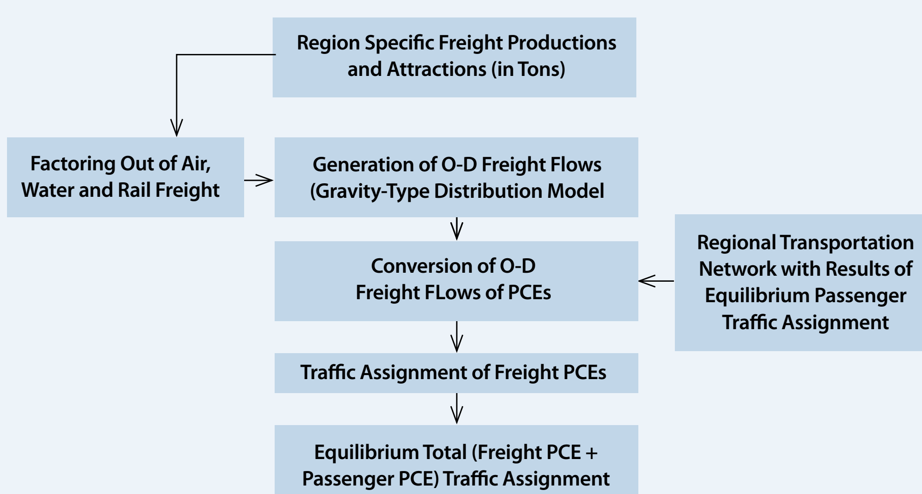
and

➤ Example Application 1: Making the Most of Existing Data Sources Metropolitan Truck O-Ds

Giuliano et al. (2008) show how a variety of existing freight data sources can be used to estimate a set of regional truck freight flows, in their case for the Los Angeles metropolitan region in Southern California. This is accomplished using the following four-step process.

1. Estimate commodity specific interregional and international trip attractions and trip productions for those locations where airports, seaports, rail yards, or regional highway entry points are located.
2. Utilize a regional input-output transactions table to estimate *intraregional* commodity-specific trip attractions and trip productions, and allocate these to small-area units.
3. Create a regional commodity origin-destination matrix using estimates from (1) and (2) and a gravity type distribution model, and
4. Load the resulting O-D matrix onto a regional highway netword with known passenger flows, using an equilibrium traffic assignment model.

In this process, they make use of the US Commodity Flow Survey, WISERtrade (monthly reports and exports by mode and customs direct), Waterborne Commerce annual tons of foreign and domestic seaport trade, and small area employment data from the Southern California Association of Governments (SCAG), among other sources. In doing, dollar valued economic activity is converted to tons of freight, which in turn are converted to passenger car equivalents (PCE) for joint passengers-plus-freight traffic routing purposes. This data are used to estimate the tons of freight moved into, out of, within, and through the region, and is combined with estimates of annual county level inbound/outbound flows, as well as state and national level foreign imports and exports information generated by a 509 industrial sector version of the IMPLAN (IMPLAN Minnesota Group, Inc) input-output model. As shown in the diagram below, the data are used to filter out all water, rail and air freight movements, leaving tons of truck freight, which is then distributed between traffic zones using a gravity model. The result, in O-D tons, is converted to PCEs, added to SCAG's estimated automobile link flow volumes, and loaded onto the region's highway network using an equilibrium assignment model. The estimated truck flows are then compared against data from 18 regional, 24-hour averaged screenline counts, using actual truck counts collected by the California Department of Transportation and SCAG. See reference *(51)* for details.



The study exemplified both the variety of data sources required to create a set of regional truck freight flows, as well as the range of modeling techniques and the sequential steps needed to pull such data together in an internally consistent manner.

$$\sum_{i=1,Z} T_{ijm} = D_{jm} \qquad \text{for all } j \qquad (27)$$

That is, the model-generated "trip ends" are constrained to equal the input data trip ends, a benefit of using a multiregional I-O model that can as a result ensure an internal consistency between regional production and demand totals, as well as between industrial sectors. Model calibration techniques include ordinary least squares log-linear regression and custom built, maximum likelihood based gradient search methods, embedded in iterative proportional fitting routines that ensure a match between modeled and observed origins and destinations.

A useful characteristic of the I-O based approach is that the flow modeling step can be kept separate from the trip end modeling in order to calibrate a set of m = 1,2, . . . N different, commodity-specific interaction models using a single conceptual framework. Alternatively, the entire freight production, consumption and distribution process can be solved by employing a "round-by-round" iterative process that cycles until a balance between TAZ based production, consumption and commodity trades (i.e., flows) has been achieved, across all analysis zones and across all industrial sectors.

US applications of I-O based commodity flow models at the statewide level usually produce a set of commodity class specific, intercounty flow matrices. *(1, 62, 63)* The use of I-O based trip generation, attraction and distribution modeling has also begun to find its way into substate (*64,* see also *8*) and metropolitan area modeling. *(50, 65)* As multicounty metropolitan regions grow in geographic size, it seems logical to expect analysts to use a combination, or hybridization, of engineering inspired vehicular trip based methods of flow estimation and commodity-flow based methods inspired by spatial economics.

14.3.4.3 Modal Share Estimation

Perhaps the most difficult of all the dimensions of freight demand to capture is mode selection. Given a set of O-D freight flows, the selection among the k′ = 1,2..k . . . K modes available is often modeled using the popular logit form, as

$$T_{ijmk} = T_{ijm} * P(k/ijm) \qquad (28)$$

where the probability of selecting mode k for a given i-to-j trip is given as

$$P(k/ijm) = \exp(-c_{ijmk}) \,/\, \sum_{k'=1,2,..K} \exp(-c_{ijmk'}) \qquad (29)$$

for c_{ijmk} = the cost of shipping a unit of commodity m from i to j by mode k. Here costs are usually specified in terms of an average freight rate, a network-simulated transit time, or an additive, linear combination of these and possibly other factors. For example, Southworth et al. *(25)* developed mode-specific versions of equation (3) to model the choice between truck-rail and truck-water movements, as

$$c_{ijmk} = \theta_0 + \theta_1 * f_{ijmk} + \theta 2 * t_{ijm}k \qquad (30)$$

for f_{ijmk} = the dollar valued freight rate for moving a ton of commodity m from i-to-j by mode k, and t_{ijmk} = the transit time associated with such a movement; and where θ_0, θ_1 and θ_2 are empirically derived model parameters (with the ratio θ_2/θ_1 providing a rough estimate of the value of in-transit time). Calibration can again be carried out using ordinary least squares log-linear regression or maximum likelihood methods. Note that the mode-specific freight rates themselves may also need to be modeled, where not all i-to-j flows are reported, or where the effects of variables such as significantly increased freight rates or congestion-induced in-transit times are among the questions being posed by the analysis. In *(25)* for example, the rail rates are estimated by a regression that ties rates to miles traveled, carloads per shipment, and tons per carload. Other cost factors, notably measures of service reliability, are also usually important to such mode selections. However, capturing this sort of data is difficult for aggregate, TAZ-based models and has usually been handled by disaggregate mode choice models. *(21–24)*

An alternative to the traditional aggregate logit mode choice model has been proposed by Picard and Gaudry *(66)*, who use Box-Cox transformations of the logit's explanatory variables to calibrate an aggregate intercity rail versus truck modal share model against the flows of 48 commodities within Canada. This is a technique also used in passenger mode choice modeling to generalize the functional form of the demand model. A third and significantly different alternative to logit-based mode choice modeling is derived from production theory, and specifically the duality that can be observed between production and cost functions. This approach leads to considerably more involved freight cost functions in which the volume of freight moved is included in the list of explanatory variables. In particular, and where time series or cross-sectional and time-series (including *panel*) data is available, short-term modal splits have been forecast based in part on the recent relationship between modal characteristics and the observed volumes of freight moved. This includes both Cobb-Douglas and translog models. A simple example of a Cobb-Douglas regression model in natural log form is:

$$\ln c = \ln \alpha_0 + \alpha_v \ln V + \Sigma\, k\, \alpha_k \ln p_k \tag{31}$$

where ln c = the natural logarithm of total transportation cost; V = the total volume of traffic handled (e.g., within a region, or in a travel corridor) summed across all available modes; p_k = the price (or a multifactor generalized cost or disutility of transporting) freight by mode k (for k = 1,2, . . . k′ . . .); and α_0 and α_k are model parameters. A second approach is the more involved, nonlinear transcendental logarithmic (translog) form of cost function *(17, 67, 68)*: [2]

2 A translog function is a linear combination of all possible first and second order terms in the logarithms of independent variables (i.e., functions that are quadratic in the logarithms of the variables).

$$\ln c = \ln \alpha_0 + \Sigma k \alpha_k \ln p_k + \tfrac{1}{2} \Sigma\Sigma kk' \gamma_{kk'} \ln p_k \ln p_{k'} + \alpha_v \ln V + \tfrac{1}{2} \gamma_v (\ln V)^2 + \Sigma\gamma_{kV} \ln p_k \ln V \quad (32)$$

from which, under suitable restrictions on the value and symmetry of the model's parameter values, modal cost shares, S_k ,can be computed as

$$S_k = \alpha_k + \Sigma_{k'} \gamma_{kk'} \ln p_{k'} + \gamma_{kV} \ln V \quad (33)$$

where $S_k = V_k p_k /c$, for V_k = the cost minimizing amount of freight traffic assigned to mode k. *(64)* Once this relationship between costs and freight traffic volume is established, the model can then be used to examine the impacts of changes in specific cost factors on each mode's share of the freight that needs to be moved.

The translog approach has a number of useful properties, notably its direct tie-in to the theory of a firm's production function, as well as the less restrictive assumptions it imposes on the form of the underlying cost versus volume of production (e.g., modal traffic volume) relationship. A significant disadvantage of the approach is the large number of parameters that need to be estimated. This, in turn, leads to a requirement for a large number of observations against which to fit the model.

Finally, at least one attempt has also been made to use a neural network model to estimate freight mode choice. *(69)*

14.3.4.4 Multimodal Traffic Assignments and Network Equilibrium Models

Statewide freight flow modeling also moves traffic assignment into the realm of multimodal route choice. This sort of modeling requires first of all a suitable link-node representation of the multimodal network, paying particular attention to the points at which freight may be transferred between modes, i.e., via intermodal terminals. Most statewide applications have focused on simulations over national or regional highway, railway, and inland waterway networks, with coastal or short sea shipping (and Great Lakes shipping in the United States) also captured where necessary. Air freight is usually modeled separately, as is transoceanic freight, although the increasingly global movement of freight has led some studies to link internal, land based shipments to their transoceanic sources or markets. One such land-and-sea based intermodal network database and its supporting routing software is used to estimate the ton-miles of freight moved annually with the United States, as reported by the US Commodity Flow Surveys. *(70)* This is now one of a number of different link-node representations of multimodal freight networks from which to begin a flow modeling exercise, with each *data model* of the network differing somewhat in its link-node treatment of modes, capacities and cost functions, and notably in the way it handles terminal throughputs. *(71)*

The routing models using these intermodal network representations also vary in sophistication, from simple shortest past solutions to multipath, congestion sensitive flow assignments based on Wardrop equilibrium principles (equations 13–17) or on other forms of empirically motivated link capacity constrained assignments. *(25, 71–77)* This includes the STAN network flow modeling software *(72)* developed in Canada, and the NODUS software developed for European network flow analysis. *(73)* A number of these network-based models also offer a significant alternative to the sequential calibration of the choice of mode then route. Instead they allow the simultaneous modeling of combined mode/route alternatives. This approach offers a number of advantages, as well as some limitations, when compared with the more traditional sequential approach. It places an added burden on the modeler to come up with an effective means of capturing both time-based (including on-time reliability) and rate-based aspects of mode/route choice in a consistent manner (since rates are route and not link based). Russ et al. *(71)*, for example, convert their multimodal network into an *abstract mode network* by specifying the generalized cost of traveling over a specific network link 'a', $c^g{}_a$, to be approximated by:

$$c^g{}_a = f^g{}_a + \alpha^g * t^g{}_a \quad (34)$$

where $f^g{}_a$ = the fare (freight rate) for traffic in class g, $t^g{}_a$ = the time taken by traffic in class g to transit link a, and where this link transit time is a function of all traffic using the link, v_a, by all types of network users (including passenger modes), given by the following polynomial approximation, after Crainic et al. *(78)*:

$$t_a = F\,(v_a) = t_{0a} * [\,1 + \theta_1(v_a) + \theta_2 *(\,v_a \,/\, cap_a)^{\lambda}\,] \quad (35)$$

where cap_a = the designed flow capacity of link a, t_{0a} = the free-flow transit time for link a with no other traffic on it, and θ_1, θ_2 and λ are model parameters to be determined. Once an acceptable formula and set of parameter values for doing so has been established, a benefit of this sort of approach is that it obviates the need to specify mode or route choice sets, selecting alternatives on the basis of least O-D delivery cost. This may or may not prove sensitive enough to all of the factors affecting, in particular, mode selection. However, when dealing with transnational and transcontinental freight shipments, notably shipments of low per unit value goods such as ores or grains, a natural distance-based hierarchy of modal options often emerges that makes mode selection a comparatively straightforward, distance-dependent process. Route selection can then be done on a suitable least cost basis within these different distance bands. Where navigable waterways are close by, especially for exported and imported goods, this is often the least cost modal option. Increased distance between a waterway and a shipment's production or consumption point will often mean selection of a long-distance rail move. Here trucks usually handle both the much shorter O-D movements of commodities, as well as provide access and egress to the water or rail line-haul modes, including considerable draying of goods by truck from seaports to inland distribution terminals. This often means a choice between truck-rail and truck-barge (or truck-rail-truck versus truck-barge-truck) transportation options, with both line-haul and intermodal transfer costs and time penalties affecting route selections.

Where such intermodal assignments are important options, and where traffic congestion is also a significant issue along principal routes, a method is required for capturing not only the relative movement costs associated with each mode's contribution to the delivery, but also for translating a dollar, ton, or container unit into the number of mode-specific vehicle units required (and again allowing a suitable representation of empty vehicle repositioning and backhaul legs). Where liquid or gaseous bulk commodities are being moved, such as petroleum or propane gas, other volumetric conversions may be required to get a better estimate of railcar or barge needs. Where containers are used to transport the cargo, dollars or tons may need to be translated into the number of 20-, 40-, 48-, or 53-foot equivalent units being loaded onto vessels, trains (double or single stack), or trucks. In the United States, the (motor) Vehicle Inventory and Use Survey, the Railcar Waybills sample survey, and survey data from Waterborne Commerce statistics can be used to obtain representative ton-to-truck, ton-to-railcar, and ton-to-barge conversion factors, respectively. Studies of specific freight corridors may also require detail on the number of railcars per train and number of barges per tow when modeling route-specific movement costs, especially where the nature of delivery schedules plays a significant role in modal service quality, or where labor and fuel costs are significantly impacted by the vehicle or vessel configurations in use. Getting all of this detail into a single modeling framework is challenging and is likely to lead to new multistep freight modeling frameworks. Mahmassani et al. *(79)* offer one such framework, incorporating aspects of queuing theory and rail yard sorting into a multiproduct intermodal simulation-assignment model that also uses a logit-based discrete choice model of joint shipper mode and route choice.

Given a long-range, essentially strategic view of demand forecasting to work with, the economists' spatial price equilibrium (SPE) model is a well studied approach to the prediction of interregional and intercity freight demand. When linked to network-based "computable general equilibrium" methods, this provides a powerful theoretical and computational approach to predicting freight demands in the context of transportation supply-demand balancing, or network equilibrium. Going further, by representing not only freight flows and their associated transportation costs, but also commodity prices, producer inventories and consumer demands as link or node-based network elements, it has proved possible to derive, at least in theory, an eco-

➤ Example Applications 2 and 3: Innovative Statewide Flow Modeling in Ohio and Oregon

Both the Ohio and Oregon departments of transportation have been moving away from the traditional framework of the fout-step urban transportation planning model to create more freight-relevant forecasting methodologies. In each case, current and furture freight movements are estimated within broader economic activity and land use based freight plus passenger activity modeling frameworks.

The latest version of the Ohio DOT freight model, developed primarily to study intercity highway corridors, bases its freight flow forecast on five modeling components: (1) an interregional economic activity model or production and consumption based on an input-output accounting model, (2) a land use model, (3) a 500 TAZ economic activity allocation model that uses spatial accessibility measures and changes in developed land to redistribute activity from year to year, (4) an aggregate commercial (freight) vehicle model that converts dollars of activity successively into tons, then into truckloads and finally into hourly truck movements based on payload matching of vehicle types to commodity types, and (5) a tour-based, microsimulation of short distance "commercial" travel by employees in the industrial, wholesale, retail, transportation handling and service sectors (including service, meeting, and other trip purposes, as well as goods movements). Truck flows are allocated to the states' interregional highway network and the resulting travel costs are used to reallocate flows between TAZs. *(82)*

The Oregon DOT model similarly places the estimation and year-to-year forecasting of freight flows within a more comprehensive, spatially disaggregated economic activity and land development modeling framework. This framework is a combination of seven connected modules, some aggregate representations relying on equlibrium solutions and other fully dynamic disequilibrium agent-based microsimulations. This system evolves through time in discrete year-by-year steps. It too uses an input-output based modeling approach to estimating location-specific economic activity, which is translated into light, medium, and heavy-duty truck flows between TAZs by converting monthly dollar valued goods totals into tons and then allocating these tonnages to truck size classes. In a second version of the model, Oregon2, microsimulation of commercial activity then plays an important role in determining detailed truck movements. *(28, 83)*

nomically rational balance of commodity flows between producing and consuming regions (and between shippers and carriers) a balance between the selling and buying prices that give rise to such trades. Friesz *(80)* and Crainic *(81)* provide reviews. To date, however, the relative complexity of these SPE-based model formulations as well as their data requirements has limited their practical application.

14.3.5 National and Interregional Flow Models

Multiregional input-output models are also being applied in a number of countries at the fully national level. *(9, 84)* In the United States, some state transportation departments base their commodity flow matrices on a spatial disaggregation of broad regional flow totals supplied by the federal government. *(1)* In doing so they are taking advantage of interstate and intermetropolitan, annual tonnage and dollar valued commodity flow estimates that have themselves undergone a significant amount of flow modeling, including the application of I-O data and modeling techniques in the production of national, multidimensional freight flow matrices. For within-state flow analysis, especially if applied within the traditional multistep planning framework, this usually means using these regionally aggregated flow estimates as control totals and then carrying out county-based breakdowns of flows based on sector-specific employment totals or other measures of local economic activity. Here a second option open to transportation planning departments in the United States is to acquire an already spatially disaggregated and commercially offered set of flows, known as the Transearch freight flows database (IHS Global Insights), which is a model-enhanced synthesis of a number of freight datasets. *(1)*

In the United States, the US Department of Transportation's Freight Analysis Framework (FAF) provides an extensively documented national freight flow database, supported and distributed by the Federal Highway Administration. *(85)* The framework can be viewed as a two-step process. The first step, which makes extensive use of data modeling techniques, produces a base year freight flows matrix. The second step then applies modeling to this base year matrix to produce a set of future year freight flow forecasts. Step one represents an integration of a large number of national freight movement datasets, based on the shipper survey-based US Commodity Flow Surveys (CFS) supplemented by a number of mode specific, carrier survey based datasets for rail, inland barge, Great Lakes and Deep Sea water, air freight, and petroleum pipeline flows. At the core of this data integration process is a multidimensional, log-linear flow model that estimates the many gaps in what is a multimillion cell freight flows matrix. This step is necessary because the data sources are by themselves insufficient to provide a fully "saturated" flows matrix that simultaneously captures the origin, destination, commodity and modal dimensions of demand. This national flow model has the following form *(86)*:

$$T_{jmk} = \tau_0 * \tau_i^{O} * \tau_j^{D} * \tau_k^{K}\, \tau_m^{M} * \tau_{ik}^{OK} * \tau_{jk}^{DK} * \tau_{mk}^{MK} * \tau_{ij}^{OD} * \tau_{im}^{OM} * \tau_{jm}^{DM} * \tau_{ijk}^{ODK} * \tau_{ijm}^{ODM} * \tau_{imk}^{OMK} * \tau_{jmk}^{DMK} * \tau_{ijmk}^{ODMK} \quad (36)$$

where T_{ijmk} = the tons of commodity class m shipped annually from origin region i to destination region j by mode k. The τ's are a set of model estimated parameters that will return the original cell estimates. For example, τ_{ij}^{OD} returns the impacts of O-D separation on any {ijmk} cell estimate, while τ_i^{O} represents the size of origin effect, and τ_0 is a grand mean effect that scales all flows to the correct size. The model is solved in its natural log form. Given a completely filled in flows matrix, equation (36) will reproduce the original flow cell values exactly. In practice the many missing values that exist in what is a 131(O) * 131 (D) * 43 (M) * 7 (K) matrix of flows are filled in using a maximum likelihood parameter estimation method linked to a multidimensional iterative proportional fitting (IPF) routine. This IPF is designed to handle not only the above four dimensions of flow, but also multiple years of data as well as expansions to consider alternative freight activity measures (specifically, tons or dollar value trades) and, in principle, weighted contributions of alternative data sources to specific one- and two-dimensional "faces" of the required four-dimensional matrix. The seven modes reported are truck, rail, water, air, multiple modes and mail, pipeline, and "other and unknown." The 131 regions consist of the nation's largest 50 metropolitan areas, principal border crossing ports, and a set of rather broader rest-of-state regions. The current framework links these internal-to-the-US flows to a separately generated set of import-export shipments, based on a further synthesis of US seaport to foreign region shipments (currently seven global regions in all). Figure 14-3 shows the FAF TAZs.

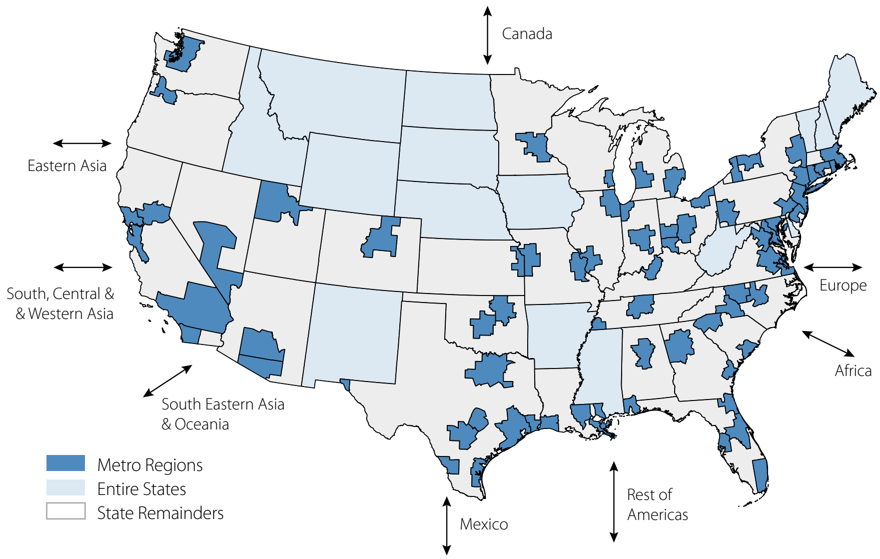
The latest FAF Version 3 forecasts use a 2007 base year commodity flow matrix as a starting point. Both long-range (to 2040) and short-range (annual, starting with 2009) flow forecasts have been created. The former long-range forecasts are by far the most data intensive and make use of an elaborate and well established commercially supplied set of economic activity forecasting tools that are themselves the result of many person-years of model development. *(87)* This includes linked models of domestic business growth, interindustry interaction, and growth in world trade based on a variety of economic, demographic, and institutional drivers. In contrast, the annual updating process is based upon relatively simple growth factor methods. *(88)* For strategic capacity and future congestion analysis purposes, FAF forecasts of commodity flows by truck are also assigned to a detailed representation of the US highway network. (Figure 14-3)

Other annually based national flow models have also been developed for selected commodity classes. Using CFS data as their observed matrix of annual state-to-state commodity flows, Celik and Guldman *(89)* provide an alternative aggregate flow model formulation to the popular gravity and I-O based spatial interaction models. Based on Brocker's theoretical framework, *(90)* they use a Box-Cox formulation to construct a model of dollar valued annual interstate commodity flows that incorporates additional variables of the type often used in international trade flow models. Treating the multiplicative form of the gravity model as a special case among a range of possible functional forms, and using a Box-Cox transformation on both dependent (Y) and independent (X) variables, they fit a model of the general form

$$(Y^{\theta} - 1/\theta) = a_0 + a_1X_1 + a_2 *(X_2^{\lambda} - 1/\lambda) + \ldots\ldots + a_n *(X_n^{\lambda} - 1/\lambda) + \varepsilon \qquad (37)$$

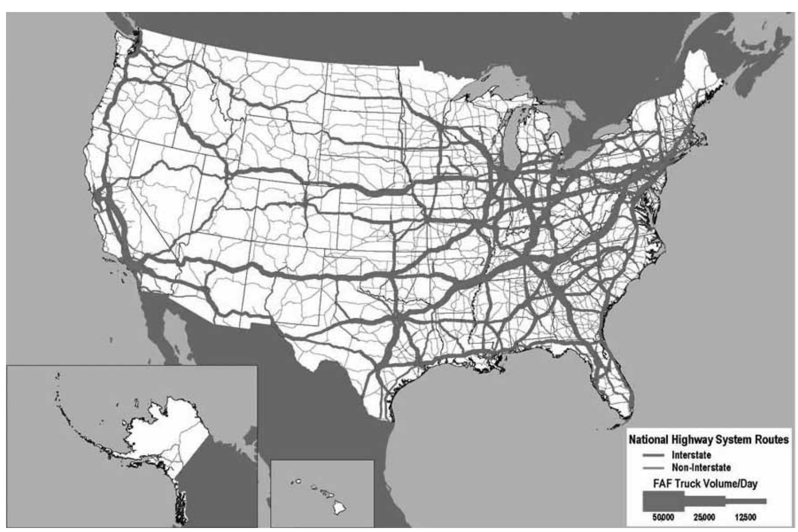
where X_1 represents a dummy variable and ε is an assumed normally distributed unobserved error term. Sixteen flow models, representing 16 different commodity classes were fitted. Reflecting the basic ideas underlying I-O

Figure 14-3 FAF3 TAZs and forecast average daily long-haul freight traffic on the National Highway System in 2040



Notes: Metropolitan areas are shown in blue. Not shown: Alaska and Hawaii.

SOURCE: Southworth, F. et al. (2010) The Freight Analysis Framework, Version 3: Overview of the FAF[3] National Freight Flow Tables. cta-gis.ornl.gov/faf/Documentation.aspx



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

SOURCE: US Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010. See Alam, M. (2010) Network Assignment of Highway Truck Traffic in FAF[3]. cta-gis.ornl.gov/faf/Documentation.aspx

based flow models, the independent variables set includes origination and destination-specific measures of sectoral employment and value added, as proxies for production and consumption, as well as population size and income per capita as proxies for final demand conditions. Average establishment size is used to capture possible production economies of scale as plant size increases within an industrial sector. Transport cost is represented by a simple average distance variable, but spatial separation effects are also reflected in a competing destination measure, as well as in an intervening destination opportunities variable. Three (0,1) dummy variables are also used. One is used to recognize states that have a common border, and a second and third dummy are used to identify if the origin and destination states contain at least one customs district, suggesting significant import or export–based flows. Celik *(91)* has also compared the above Box-Cox formulation with an artificial neural network (BP-NN) approach, as a possible option for short range O-D flow forecasting.

In Europe, freight analysis frameworks within nations and throughout the European Union have been under development since the early 1990s. The latter include freight demand forecasting components under the various acronyms of ASTRA, EUFRANET, EXPEDITE, NEAC, STEAMS, SCENES, and STEMM. State-of-the-art national freight demand models include TEM-II and SMILE in the Netherlands, SAMGODS and its successors in Sweden, NEMO in Norway, WFTM in Belgium, MOBILEC in Belgium and the Netherlands, SISD in Italy, and GBFM in the United Kingdom. *(8-10)* While each modeling framework offers advantages in specific areas, a number of common traits are evident. First, input-output modeling has become a popular means of generating both the production of and demands for commodities within specific zones/regions. While fully specified interregional input–output models are not usually being implemented and may be a little too restrictive for some uses, models such as SMILE and STREAM/SCENES employ national, interindustry input-output tables. In the case of SMILE the model employs national make/use tables to link a region's industrial activities to its freight products and needs. *(18, 92)* Where the I-O framework is perhaps most useful is in its treatment of the destination side of the freight movement picture, since, unlike data on industrial production, data on spatially disaggregated industrial consumption, which often requires multiple product inputs, is generally much more difficult to come by. *(25, 61)*

Continuing empirical research into multiregional I-O tables reported in the early 1970s by Polenske *(93)*, the US Department of Agriculture has also produced a national, multiregional I-O model that offers an innovative treatment of the role played by the freight transportation sector itself when estimating interstate commodity flows. *(94)*

14.3.6 Foreign Trade and International Freight Flow Models

The literature on modeling international freight movements is closely linked, as might be expected, to the literature on international trade. From the 1970s on, the neoclassical economic trade models by Ricardo and Heckscher-Ohlin-Samuelson started to be replaced by an industrial–organizational approach to trade also known as new trade theory (NTT). Enabled in part by much better computational resources, NTT has replaced overly simplistic trading models based on perfect competition and constant returns to scale with models that recognize

- aspects of imperfect competition,
- increasing returns to scale with high volumes of intraindustry as well as interindustry trading,
- the growth of large multinational firms, and
- “network effects” that show the benefits of having other trading partners gain in what is now an increasingly active and politically complex global commodity trading network.

By incorporating such concerns within what has also been termed the “new economic geography,” economists and regional scientists now offer a range of models for predicting trading volumes between nations. *(95, 96)*

Not surprisingly, however, these modeling efforts still rely in many instances on the use of gravity-like spatial interaction models, if modified and extended in various ways. In particular, the existence of time-series data on dollar-valued trades between nations allows the fitting of generalized gravity models. For example, Baltagi et al. *(96)* used panel data to fit the following log-linear regression model of bilateral trade flows between, on one side, the economies of the United States, Japan, and a block of 15 European Union countries and, on the other side, their 57 most important trading partners, for the period 1986-1997:

$$\ln T_{ijt} = \delta \underline{X}_{ijt} + \alpha_i + \beta_j + \gamma_t \;\; \alpha\beta_{ij} + \alpha\gamma_{it} + \beta\gamma_{jt} + \varepsilon_{ijt} \qquad (38)$$

where $\ln T_{ijt}$ = the natural log of real bilateral exports between countries i and j in year t; and $\underline{X}_{ijt}$ = a vector of explanatory variables, which replace the gravity model’s typical “trip end” variables with gross domestic product (GPD) derived indexes, including (a) the log of the sum of GPD in countries i and j, (b) a measure of the similarity in the size of GDPi and GDPj , and (c) a measure of the differences in the logs of per capita GDP. Similarly, the transportation cost variable in $\underline{X}$ is given by the difference in imports measured in c.i.f. (cost, insurance and freight) and exports measured as f.o.b. (free on board) values on real exports from i to j.[3] The α_i , β_j, and γ_t are fixed exporter, importer, and time effects (called *main effects* in log-linear modeling; cf. equation 36), and $\alpha\beta_{ij}$, $\alpha\gamma_{it}$, and $\beta\gamma_{jt}$ are unobserved interaction effects between, respectively, importer-exporter nations, unobserved exporter nation-specific time varying effects (e.g., its business cycles, political and institutional characteristics), and unobserved importer time varying effects; and ε_{ijt} are remainder, or unexplained error terms. Similar models are reported elsewhere.

3 See Incoterms at www.iccwbo.org/incoterms/ for definitions of these and related terms.

In addition to the above country-to-country trade flow models, a number of planning and forecasting studies focus on a single commodity or industrial sector and trace its shipments across state and also international boundaries. This involves movements of freight across distances of hundreds and even thousands of miles, and usually through a number of intermodal transfers, notably at seaports. These are effectively global trade flow models with a strong interest in reflecting the effects of different freight movement technologies and transportation system capacities on shipment costs, and therefore on future patterns of trade. Having emerged out of a different modeling paradigm from the sequential transportation planning methods described above they offer a style of freight flow modeling based in optimization theory.

A good example is provided by Wilson et al. *(97)* in their modeling of world grain trade. Solved using the popular GAMS software, this model is used to examine the delay costs associated with moving grains (corn, wheat, and soybeans) down the Mississippi River system and to project river traffic volumes 10, 20, and 30 years into the future. In this instance a combined solution to mode selection and source-market allocation is offered for a given set of production and consumption forecasts. This is done by solving a nonlinear optimization problem, assigning grain specific O-D flows such that exporting regions' production as well as shipping costs are minimized. The model's objective function can be stated as:

$$\begin{aligned}&\text{Minimize } \Sigma_i \ \Sigma_g \ (PC_{ig} - s_i) * A_{gi} + \Sigma_i \ \Sigma j \ \Sigma_g \ c_{ijg}{}^{k=truck} V_{ijg}{}^{k=truck} + \\ &\Sigma_i \ \Sigma_w \Sigma_g \, c_{ijg}{}^{k=rail} V_{ijg}{}^{k=rail} + \Sigma_i \ \Sigma_w \Sigma_g \ c_{iwg}{}^{k=truck} V_{iwg}{}^{k=truck} + \\ &\Sigma_i \ \Sigma_p \Sigma_g \ c_{ipg}{}^{k=rail} V_{ipg}{}^{k=rail} + \Sigma_w \Sigma_p \Sigma_g \,(c_{wpg}{}^{k=barge} + L_p{}^{k=barge})* \\ &V_{wpg}{}^{k=barge} + \Sigma_p \Sigma_q \Sigma_g \,(c_{pqm}{}^{k=ship} + r_q{}^{k=ocean\ shipping}) * V_{pqg}{}^{k=ocean\ shipping} \qquad (39)\end{aligned}$$

where i = domestic production region, j = domestic consumption region, p = index of ports in exporting countries, q = index of ports in importing countries, w = index of river access point, k = mode (barge, rail, truck or ocean shipping), PC_{ig} = production cost of grain g in region i; s_i = production subsidies in the exporting country; r_q = import tariffs in the importing country; L_p = delay costs associated with barge shipments; and c = transport costs per ton at each stage in the freight supply chain. The objective function *(39)* is solved subject to upper and lower bound constraints on region specific crop supply, lower bound constraints on the demands that need to be met for specific grains in specific export and domestic consumption regions, and physical constraints on the rail, river and port system used to handle these flows. *(97)*

A considerable amount of data from a variety of sources needs to be pulled together in order to calibrate models of this type. This includes some inputs that are themselves the result of modeling, notably mode specific freight rates, network link capacities, and future demand forecasts (in the above case these were based on externally provided regional income and population projections). Once a base year model has been calibrated and a set of demand and supply forecasts have been constructed, however, a large number of different scenarios can be experimented with. This includes scenarios that contain different rates of overall, as well as commodity specific, traffic growth. The challenge here is to capture the changes expected in specific commodity flows and in their costs, subject to the many other different types of freight that are also likely to be moving over these same transportation networks.

14.4 Hybrid Modeling Frameworks and New Data Sources

The most promising freight demand modeling frameworks incorporate a variety of not only different data sources but also different modeling techniques. Where estimates or forecasts of complete regional O-D flow patterns are required, this situation is likely to become the norm. Such a concept encourages the use of cross-sectional and time-series modeling of major freight traffic generators as components of both metropolitan and statewide freight planning models. The flows being forecast by these regional planning models can also draw either comparisons with, or control totals from, the broader regional freight activity forecasts supplied by federal modeling programs (such as the FAF in the United States). The modeling of international trading in commodities adds one more piece to the freight analysis puzzle. Better integration of domestic and international freight flow modeling is needed. Recent commodity specific applications of global trade flows point to the need to track complete source-to-market intermodal supply chains, over time as well as over space, and across international borders. New, including remotely sensed, freight data collection technologies should help with this, if private-sector concerns over the use of proprietary information can be dealt with effectively. GPS, passive and active radio frequency identification (RFID), barcodes, and other vehicle, container, and cargo tracking technologies promise the collection of a great deal of detailed freight movement data at a steadily decreasing acquisition cost. How public-sector freight planning agencies gain access to and subsequently bundle this data is going to be a key to improved freight flow models.

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15

Financial Strategies for Delivering Intermodal Freight Facilities

David Seltzer and Catherine Reddick

15.1 Introduction

Freight transportation involves a wide array of services, facilities, and operating structures supporting aviation, marine, rail, and road infrastructure. Twenty years ago, the intermodal connections between freight carriers were not as conspicuous an element in the nation's goods movement network. Just-in-time delivery schedules and supply chain management did not figure as prominently in the national economy, and e-commerce had yet to be invented. Railroads paid for their own rights-of-way and terminals, highways could be readily financed from the growing Highway Trust Fund, and ports had yet to face the pressures of burgeoning international containerized trade.

As a result of various factors—including dramatically increased trade volumes, narrower profit margins on manufactured products, and greater deregulation of carriers—intermodal connections have assumed an increasingly critical role both in the efficient functioning of America's goods movement system and in the growth of the national economy. It is increasingly evident that traditional funding sources and methods of financing infrastructure improvements have become inadequate for the highly capital-intensive and multijurisdictional nature of large intermodal freight facilities. At the same time, communities have become more sensitive to the substantial externalities associated with the growing volumes of cargo transported through their region by road and by rail.

Prior chapters have explored how capital investment decisions made by project sponsors determine whether or not a facility will be built. Chapter 4 described why there is public-sector participation in the nation's goods movement sector, which is operated almost entirely by private businesses. This chapter looks at the *financing decision,* rather than the *investment decision,* for intermodal facilities. It examines how such projects, once selected, are organized, delivered, and paid for—i.e., their *financial strategy*. Empirical evidence from "done deals" is used as the basis for describing how—and why—freight projects are structured in different ways.

It must be acknowledged at the outset that analyzing intermodal infrastructure investment presents several challenges. First, there is the definitional problem: In the transportation sector, no single definition exists as to what constitutes an *intermodal facility*. In some cases, the term is used to describe a terminal where cargo is transferred from one mode to another. In other cases, the term refers to the ground access infrastructure—both the regional highway and rail corridors linking distant metropolitan areas and the "last mile" connectors directly serving the terminal. In many instances, the intermodal facility consists of both a terminal and the rail or highway infrastructure connectors and corridors that serve it.

Second, there is no uniform agreement on how to distinguish an intermodal facility from other freight terminals that might more properly be considered *intra*modal in nature (for example, a rail marshaling yard, an air freight hub, or a trucking distribution center, each of which involves little or no transfer of goods between different transportation modes).

Third, the transportation infrastructure to a large extent consists of shared-use assets, which accommodate both cargo and passengers; these include airports, rail lines, and access highways. Even for freight-only projects, it is arguable whether certain investments, such as double tracking 1,000 miles of railroad right-of-way between the Midwest and the West Coast, is truly intermodal in nature. The term *intermodal facilities* thus encompasses a diverse range of freight-related capital investments.

To resolve this definitional problem, a list of all projects labeled as intermodal facilities over the past decade and a half was derived from recent federally sponsored research on freight infrastructure investment. (*1, 2*) This list of some 50 existing or proposed freight-related projects was then culled down to 35 projects that have been completed or that have sufficiently finalized their arrangements for funding and financing the project to allow detailed analysis. (See Table A-1 at the end of this chapter.)

This chapter seeks to explain the financial strategies for intermodal investments by presenting a conceptual framework for categorizing the 35 projects according to their key features. This "taxonomy" does not endeavor to determine whether those strategies resulted in the best capital investment choice; nor does it seek to evaluate how the projects performed financially or operationally once completed. Rather, the purpose of this analysis is to reveal which financial arrangements appear best suited to advance different types of intermodal facilities.

15.2 Financial Strategies

Much of the industry literature employs the terms *financing* and *funding* interchangeably, drawing little distinction between a borrowing tool and the revenue stream that secures it. To understand how projects are advanced, this chapter differentiates *funding* (the underlying source of revenues used to pay for a project) from *financing* (the transaction mechanism used to convert a multiyear funding stream into upfront capital for investment). Accordingly, highway tolls, real estate tax surcharges, and port terminal fees are each properly considered *funding sources,* whereas toll revenue bonds, tax increment obligations, and concessionaire equity investments represent *financing tools* used to capitalize those revenue streams.

A project's financial strategy therefore can be viewed as the approach through which its capital investment is structured, funded, and financed. The three principal elements of this strategy are

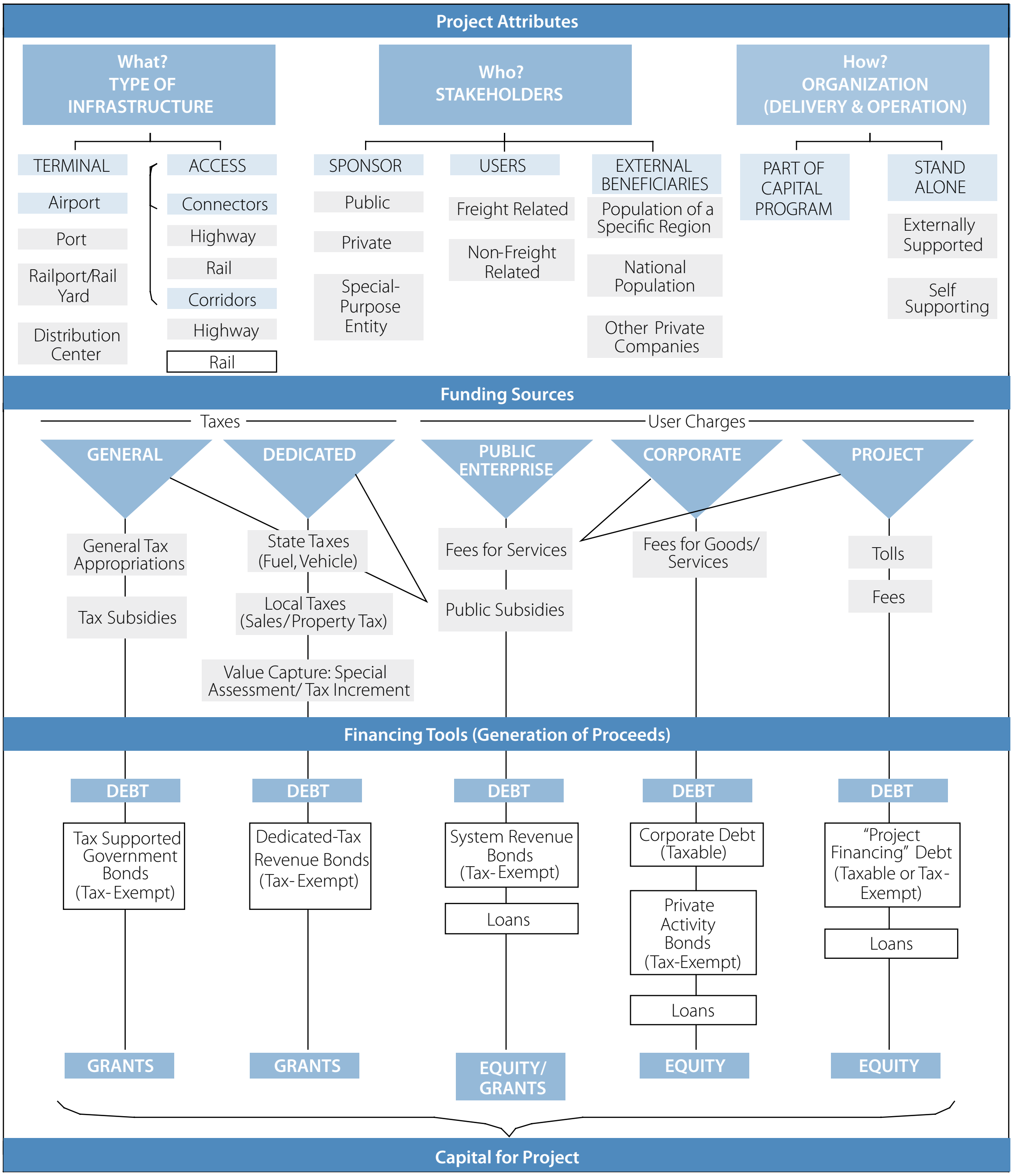
- The project attributes, such as its physical characteristics, governance structure, and stakeholders, which together determine its structure;
- The funding sources, or underlying revenue streams, identified to pay for the project; and
- The financing tools, or mechanisms, used to capitalize (generate proceeds from) those funding sources, providing upfront capital for the investment.

Project attributes determine the suitability of various funding sources, which in turn are associated with different financing tools. Figure 15-1 depicts the framework for classifying the financial strategies employed to deliver intermodal freight projects. The figure links different potential revenue streams with the financing tools relevant to them. For example, a dedicated funding source, such as a sales or fuel excise tax, is used to secure special tax revenue bonds; project-based user charges, such as tolls and fees, support debt service on project revenue bonds.

Six specific projects, described in sidebars placed throughout this chapter, were selected because they reflect the diverse nature of intermodal facilities: rail access versus highway access, rail-truck transfer terminals versus ship-rail transfer terminals, and public versus private sponsorship:

- Heartland Corridor—a series of capital projects along a 600-mile rail corridor between the Hampton Roads region of Virginia and Columbus, Ohio, that improve access among new and existing port facilities in Portsmouth, Virginia, and three new rail-truck intermodal terminals located in Columbus; Prichard, West Virginia; and Roanoke, Virginia.
- APM Terminal—a 300-acre marine terminal developed by APM/Maersk in Portsmouth, Virginia, at the eastern end of the Heartland Corridor.

Figure 15-1 Framework for classifying financial stratgies



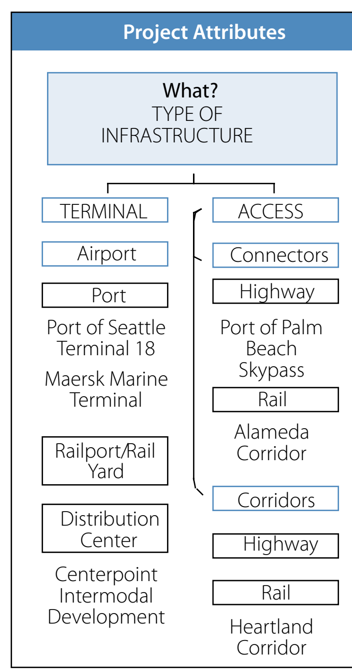
- Port of Palm Beach Skypass— a four-lane overpass for US 1, which bisects the Port of Palm Beach (Florida), thereby eliminating a highway-rail crossing and improving roadway access to and within the port.
- Alameda Corridor—a 20-mile, grade-separated, high-speed rail trench linking the ports of Los Angeles and Long Beach with major rail yards in downtown Los Angeles, consolidating 90 miles of branch rail lines, and eliminating conflicts at more than 200 at-grade railroad crossings.
- Port of Seattle Terminal 18—a marine container terminal project that expanded the size of the terminal, doubled intermodal container rail capacity, and improved ground access.
- CenterPoint Intermodal Center—a 2,200-acre facility outside of Chicago, consisting of warehouse and distribution space that serves as a major rail-truck transfer facility for the BNSF Railway.

15.3 Project Attributes

To determine how best to fund and finance an intermodal facility, it is first necessary to answer three fundamental questions concerning the project's attributes or intrinsic characteristics:

- What type of infrastructure is being developed?
- Who are the stakeholders in the project?
- How will the project be delivered and operated?

Figure 15-2 Classifying intermodal projects by attributes



While these are listed as separate questions, answering them is an iterative process. The scope of the project, its group of stakeholders, and its development approach and ongoing management responsibilities are interrelated issues and need to be addressed concurrently.

15.3.1 Infrastructure

The nature of the infrastructure project is a defining characteristic in determining the feasible set of funding and financing strategies. (Figure 15-2)

A basic distinction needs to be drawn between terminal facilities, access infrastructure, and projects that combine the two. *Terminal projects* are new construction, or improvements to existing intermodal transfer terminals. *Access projects* refer to the rail, highway, and marine trade corridors linking the terminal facility to other distribution points (corridors) or the shorter links (connectors) providing immediate access to the terminal site from existing nearby corridors. Of our six illustrative projects, the APM Terminal and the Port of Seattle Terminal

➤ The Heartland Corridor Project

Heartland Corridor is a $300 million series of freight rail capital projects improving access among new and existing port facilities in the Hampton Roads area of Virginia and in the Midwest. The largest element consists of approximately $200 million of corridor costs associated with increasing bridge and tunnel clearances along several hundred miles of track right-of-way in Virginia, West Virginia, and Ohio. The improvements will allow double-stack container trains to travel from the Port of Virginia to markets in Columbus and Chicago.

Construction commenced in 2006, and completion was targeted for the end of 2010. The Heartland project also includes three new rail-truck intermodal terminals located in Columbus, Ohio; Prichard, West Virginia; and Roanoke, Virginia. The cost of the terminal projects totals approximately $95 million. A last-mile connector project costing $60 million will relocate 4.5 miles of the Commonwealth Railway line to the median of the Western Freeway (I-61/I-664) in Portsmouth, Virginia. When the freeway was built nearly three decades ago, its median was designed to accommodate a dual set of rail tracks. This rail corridor will serve the new APM/Maersk and Craney Island marine terminal facilities in Portsmouth.

Public-sector stakeholders for the corridor improvements include the Eastern Federal Lands Division of the Federal Highway Administration, the Virginia Department of Transportation, the West Virginia Department of Transportation, and the Ohio Rail Development Commission. Norfolk Southern Railway is the principal private stakeholder. The parties have entered into a memorandum of agreement setting forth respective project responsibilities.

There is no actual "Heartland Corridor" organizational entity; rather, each component of the Heartland project is advanced by the relevant parties as part of their respective capital programs. For example, the Federal Highway Administration is the project sponsor and the coordinator for the federal funding and environmental compliance work. Norfolk Southern is responsible for the rail design and construction work. The Rickenbacker Intermodal Terminal in Columbus is sponsored by the Columbus Regional Airport Authority. The other intermodal facilities along the corridor are organized and sponsored by local entities. The Heartland Corridor does not generate its own project-specific revenues; instead, it is reliant on capital contributions from the stakeholders to fund the various components.

Funding for the rail corridor improvements is derived from a combination of federal grants, state grants, and capital investments funded by Norfolk Southern. The capital costs are being funded by the respective sponsors largely on a pay-as-you-go basis, without the use of any financing tools specifically related to the project.

18 expansion are examples of pure terminal projects, representing new (Maersk) or expanded (Terminal 18) facilities. The Alameda Corridor project and the Palm Beach Skypass project are purely local connector projects; rather than involving the construction of new terminal facilities, they improved rail and road access, respectively, to existing terminals. The Heartland Project encompasses a several-hundred-mile-long corridor capacity expansion, linking the Chesapeake Bay with Midwest distribution centers.

Many intermodal freight projects include both terminal and access components as part of a unified development. The CenterPoint Intermodal Center development entails sizable terminal and access components. While combined terminal-access investments are often viewed as one integrated project, the primary stakeholders for each component may differ. For example, access projects can include connectors extending several miles or corridors stretching hundreds of miles, with much wider spillover effects (externalities) than a terminal transfer project at a confined site. By their nature, the various components of a project may have legal access to differing funding sources. Most government funding programs are oriented toward modal type, with specific eligibility criteria. For instance, Highway Trust Fund resources generally are limited to access projects as opposed to terminal facilities.

Finally, the allocation of funding responsibility between public- and private-sector project participants varies markedly from project to project. It generally is negotiated by the stakeholders, based on the perceived benefits to facility users relative to the public at large. To the extent the project provides greater capacity or improved efficiency for private businesses involved in transporting freight (carriers, shippers, terminal operators), there is greater opportunity to harness facility user charges as a funding source. On the other hand, if the project benefits consist principally of enhancing the surrounding communities through reduced pollution and congestion without increasing transportation productivity to the businesses utilizing it, a greater extent of public subsidies is likely to be necessary.

➤ APM Terminal Project, Portsmouth

The APM Terminal is a 300-acre, $450 million marine container terminal located on the Elizabeth River in Portsmouth, Virginia. APM Terminals, part of the Danish shipping conglomerate A. P. Moller–Maersk Group, served as the project sponsor. The Virginia Port Authority, the Commonwealth of Virginia, and the City of Portsmouth are among the public-sector stakeholders.

APM is the owner of the site and owns and operates the terminal facilities. The project is being funded entirely by APM from corporate resources, although there were significant "inland" public- and private-sector co-investments that served as incentives for the company to undertake the project. Concurrent projects included a $60 million, 4.5-mile rail relocation project along the Western Freeway to improve terminal access by eliminating 13 grade crossings, and the Heartland Project, which includes $200 million of capacity improvements to several hundred miles of Norfolk Southern right-of-way connecting the terminal to Midwest distribution points.

The project was not financed using debt specifically identifiable to the project.

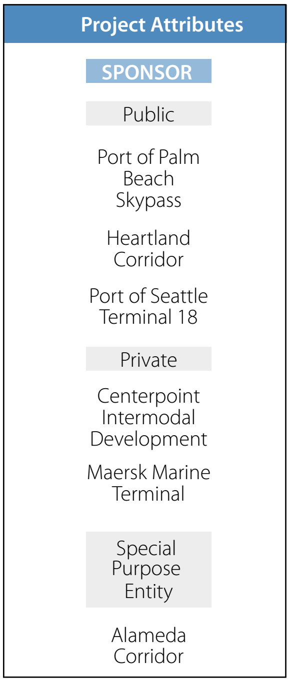
15.3.2 Stakeholders

The stakeholders in a project represent segments of the population and various public and private organizations that have a financial or nonfinancial interest in the project.

15.3.2.1 Project Sponsor

Characterizing the stakeholders in a project begins with identifying the sponsoring organization. (Figure 15-3) The project sponsor is responsible for defining the scope of the project, developing the plan of finance, arranging the participation of other stakeholders, and coordinating the project delivery and operations. Although in many cases the sponsoring organization owns the completed asset or improvement, other key project delivery responsibilities—including designing, financing, constructing, operating, and maintaining the completed or improved infrastructure—may be delegated to other organizations. Project sponsors can be classified as existing private entities, existing public entities, or special-purpose public or private entities created exclusively to develop a specific project.

Figure 15-3 Classifying intermodal projects by sponsors



Private corporate entities involved in freight transportation often serve as sponsors of intermodal projects. Maersk, a publicly traded Danish company (A. P. Moller–Maersk Group), is one of the largest shipping/container companies in the world; it served as the sponsor in the development of its new terminal in Portsmouth, Virginia. CenterPoint Intermodal Center in suburban Chicago is sponsored by CenterPoint Properties Trust, a real estate investment trust currently held by CalEaston Global Logistics, whose members include the California Public Employees Retirement System and LaSalle Investment Management. The Trust has a portfolio of over 15 million square feet of industrial real estate holdings nationwide, including intermodal transportation facilities and warehouses, but it is not a transportation operator. The participation of Maersk (a strategic investor) and CenterPoint (a financial investor) demonstrates how private-sector entities can serve as project sponsors.

Public entities are those federal, state, and local government agencies or nonprofit organizations established to provide transportation services in a defined region. The Federal Highway Administration's Eastern Federal Lands Division, with a 31-state jurisdiction, serves as project sponsor for the rail corridor portion of the Heartland Project, which spans Virginia, West Virginia, and Ohio. The Port of Palm Beach was the sponsor of the Skypass project, which was contained within the Port district's defined service area.

Sometimes, project stakeholders determine that a project would be best sponsored by establishing a special-purpose entity, whose sole mission is the development and management of that investment. The $2.5 billion Alameda Corridor is one of the largest intermodal infrastructure projects completed to date; it was developed and financed by the Alameda Corridor Transportation Authority, a public agency formed by the cities and ports of Long Beach and Los Angeles, with the two rail carriers using the corridor—Union Pacific and BNSF—participating in operational oversight.[1]

15.3.2.2 Project Users

The second key group of stakeholders consists of the users of the intermodal facility. The direct users are the carriers (cargo airlines, steamship lines, railroads, trucking companies) and the terminal operators (e.g., stevedoring companies), but the ultimate users/beneficiaries are the shippers (owners or man-

1 The planning of the project was initially undertaken by a regional public body, but because of the size, scope, and timeframe, the two ports and their municipal owners determined that a publicly created special-purpose entity would be the most effective way to deliver and operate the project. The Alameda Corridor Transportation Authority's seven-member governing board includes two representatives from each port, a member of each city council, and a representative of the Los Angeles County Metropolitan Transportation Authority. Operations are overseen by a four-member operating committee, which includes one representative each from the Port of Long Beach, Port of Los Angeles, BNSF Railway, and Union Pacific Railroad.

ufacturers of products contracting with the carriers for transportation) and their customers. While the focus of this chapter is on intermodal freight facilities, transportation infrastructure investments may serve both goods movement and passenger trips.

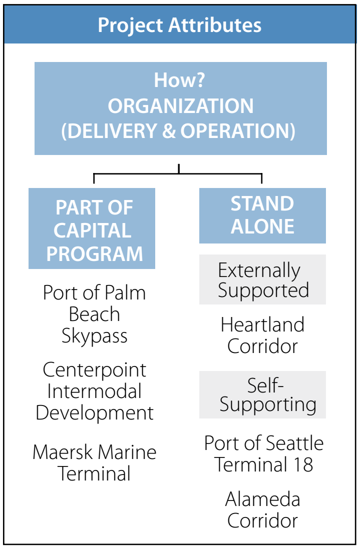
15.3.2.3 General Public

The third key group of stakeholders is the general public. For certain larger intermodal projects, the economic effects are so widespread as to be considered national in scope. For example, the ports of Los Angeles and Long Beach handle one-quarter of the nation's waterborne international trade. The effect of the Alameda Corridor on goods movement throughout the country has been cited by advocates of the project as justification for federal participation in funding a portion of the capital costs.

A major challenge in developing most intermodal freight projects is their spillover effects—economic, environmental, and mobility-related—on other groups beyond the direct sponsors and immediate users. In nearly all cases, a more limited segment of the general public—those residents living in the vicinity of a project—will be impacted by its development and operations. The affected geographic region can, however, be extensive, and the residents and workers may be represented by multiple governmental units (municipalities, counties, regional bodies, and state governments), resulting in considerable complexity. These challenges can be more acute for access projects, which generally impact broader geographic areas than site-specific terminal transfer facilities. Potential local benefits, including improvements in air quality, safety, and local road congestion, as well as economic development, must be weighed against local costs, such as increased traffic and inconvenience resulting from construction and operations.

Organizing the participation of public and private stakeholder groups in a freight project is frequently complicated by the varied objectives—between the public and private sectors, among different governmental units, and across disparate populations. The Government Accountability Office has noted that a "system-wide approach" to intermodal freight financing improves project outcomes. This approach includes various strategies for ensuring the efficient participation of stakeholder groups, including: coordination across modes and jurisdictions, productive involvement of private-sector stakeholders, and analytical evaluation of costs and benefits to prioritize infrastructure investments and determine the appropriate balance of funding provided by various stakeholders. (*3*) Identifying and accessing all stakeholders and their potential funding sources at the outset is essential to designing an efficient and equitable financing strategy for implementing the project successfully and in a timely fashion.

Figure 15-4 Classifying intermodal projects by organizational status



15.3.3 Project Delivery and Operations

The stakeholders for an intermodal project collectively determine the "how"—what is the most appropriate strategy for delivering and operating the project, starting with identifying the project sponsor. (Figure 15-4)

If the intermodal project is delivered as part of an existing corporate or governmental sponsor's ongoing capital program, it is just one element of a broader capital investment plan supported by organization-wide resources. The intermodal facility, once delivered, could be either managed by the project sponsor itself (a corporation or governmental enterprise) or leased to a tenant/lessee that would conduct operations.

A project can be considered *stand-alone* if it is developed, operated, and/or financed in a manner different from the balance of projects in the organization's capital program. Stand-alone projects can be sponsored by a private corporation, a public agency, or a special-purpose entity where the project's size, complexity, or risk profile—and specific revenue stream—warrants special organizational arrangements. For example, the Port of Seattle's Terminal 18 project was structured as a stand-alone obligation distinct from the balance of the Port's capital program. It is backed solely by the projected lease rental payments from SSA Terminals, the private operator/tenant, rather than the general resources of the Port.

The previous discussion on identifying the stakeholders noted that a separate legal entity may be established, whose governance structure, administrative responsibilities, and financial participations are custom-crafted based on the unique features of the project. As discussed further under Funding Sources (below), if the project is to be supported predominantly or exclusively from the project's self-generated revenues such as tolls or fees, it is considered *self-supporting*. If the project will be implemented using general resources of the sponsor or subsidies from another entity in whole or in part, it is considered *externally supported*.

The defining feature of a stand-alone project is its "one-off" strategy and structure; examples include the Alameda Corridor and Heartland Corridor projects. In the case of the Alameda Corridor, the stakeholders created a special-purpose entity responsible for delivering and operating the improved rail access infrastructure. The Heartland Corridor represents the combined efforts of numerous public and private stakeholders, who adopted a cooperative approach to implement this extensive and unique undertaking. If substantial expansions serving different beneficiaries were to be pursued for either Alameda (extending it eastward) or Heartland (extending it westward), it seems likely that a new organizational framework would need to be arranged, involving new stakeholders and different arrangements for risk allocation and funding responsibility.

Key attributes of the six projects are summarized in Table 15-1.

➤ **Table 15-1** Key attributes of six sample intermodal projects

Project Attributes	Type of Infrastructure	Sponsor	Financial Structure	
Heartland Corridor	Rail access to ports and rail-truck facilities	Public	Stand-alone	Externally supported
APM Terminal Development	Marine terminal	Private	Corporate capital program	Self-supporting
Port of Palm Beach Skypass Project	Road access to port	Public	Governmental capital program	Externally supported
Alameda Corridor Project	Rail access to ports	Public (Special-Purpose Entity)	Stand-alone	Self-supporting
Port of Seattle Terminal 18 Expansion	Marine terminal	Public	Stand-alone	Self-supporting
CenterPoint Intermodal Center Development	Rail-truck and truck distribution facilities, and access	Private	Capital program	Self-supporting

15.4 Funding Sources

The second of the three elements informing the financial strategy for delivering intermodal facilities is identifying the funding source or revenue stream.

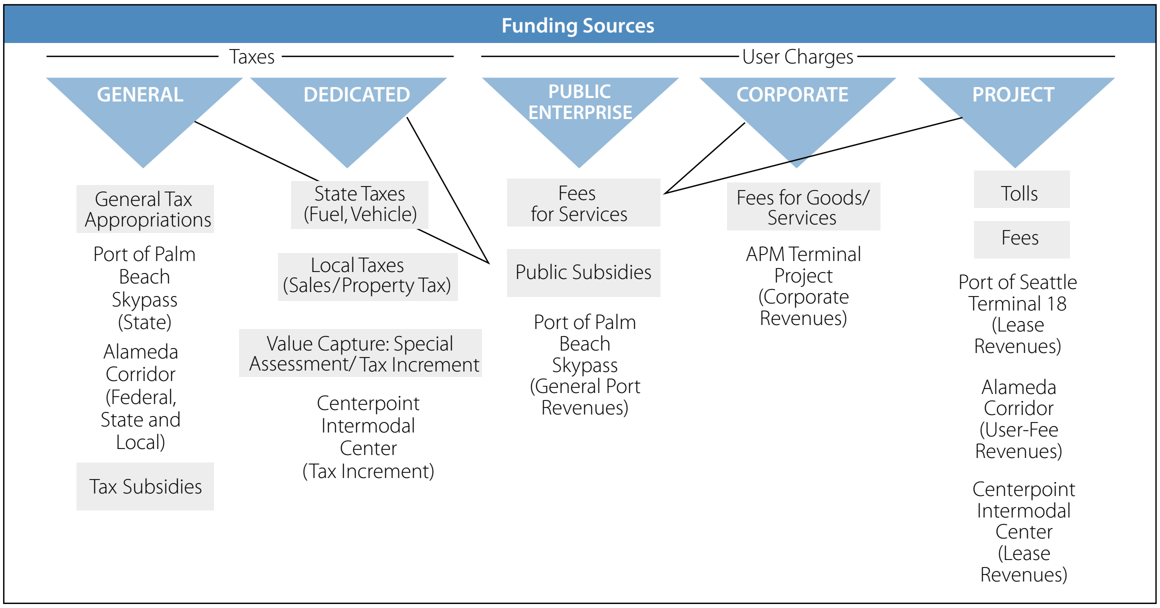
Fundamentally, there are two basic sources of revenue for publicly funded infrastructure projects: taxes and user charges. (See Figure 15-5) Taxes are compulsory public charges levied on a product, income stream, or activity with no direct receipt by the taxpayer of a good or service in return. In contrast, user charges, broadly defined, represent commercial charges imposed by governmental or private entities and paid by a voluntary purchaser, in exchange for receipt of a good or service. These two broad categories can be further delineated, as described below.

15.4.1 Taxes

Intermodal projects can receive both general governmental tax support and dedicated "special" tax revenue streams.

General tax support refers to financial assistance backed by the governmental entity's general credit, rather than a single, specific revenue source. Federal, state, or local governments may subsidize both capital and operating requirements of intermodal projects from their general funds. Capital support may take the form of direct grants for capital outlays, as well as annual appropriations to support debt service on bonds issued by that entity or another governmental unit to fund capital projects. For example, the Commonwealth of Pennsylvania provides both direct grants for freight projects using general obligation bond proceeds and yearly appropriations from current revenues to support principal and interest payments on bonds issued by the Philadelphia Regional Port Authority.

Figure 15-5 Project funding sources



Tax subsidies refer to foregone governmental tax receipts resulting from granting deductions, credits, or exclusions that are provided as tax incentives to induce private investment. Although not a direct outlay of public funds, these fiscal incentives (known as tax expenditures) are ultimately paid for by the general credit of the governmental unit. Tax incentives relevant to freight facilities include the use of tax-exempt private activity bonds (below-market rate borrowing), Railroad Track Maintenance Credits, Foreign Trade Zones (exemptions from duties), and federal Empowerment Zones (enhanced depreciation deductions and tax credits).

Dedicated tax revenues refer to defined tax revenue streams whose funding is pledged specifically to a sponsor for transportation purposes. The most common dedicated tax at the federal level is that for the federal-aid program, where fuel excise and other related taxes and fees are collected and deposited in the federal Highway Trust Fund and made available to states for surface transportation projects. The assistance is either apportioned (through distribution formulas to states), earmarked (by congressional direction), or allocated (at the discretion of the secretary of transportation).

Dedicated taxes at the state or local level can take the form of either a special-purpose tax pledged exclusively for transportation purposes or a designated portion of a broader general tax. Most states impose transportation-related taxes and fees, such as motor fuel excise taxes and vehicle registration fees, and deposit them in state trust funds legally restricted for transportation purposes. Such dedicated taxes effectively represent indirect charges to users of the infrastructure. When direct user charges are not feasible, these trans-

➤ Port of Palm Beach Skypass Project

The Skypass Bridge project consisted of the construction of a four-lane overpass on US Route 1 that eliminated a major highway-rail crossing at the Port of Palm Beach, Florida. Prior to the overpass construction, the port was bisected by US 1, which separated the Florida East Coast Railway yard and storage facilities on the west side of the port area from the waterfront and marine terminal facilities on the east side. The construction of the overpass was completed in 1999. The bridge project improved roadway access both to and within the port. (*2*)

The governmental stakeholders are the Port of Palm Beach, the Florida Department of Transportation, and the Florida Office of Trade, Tourism, and Economic Development. Private stakeholders include both Port of Palm Beach users (shippers and terminal operators) and motorists and truckers using US 1.

The Port of Palm Beach District served as the project sponsor. The Port is an independent special taxing district covering approximately 971 square miles in Florida's Palm Beach County. It has the authority to levy an ad valorem millage tax (but has not done so since 1975). Fees charged for wharfage, dockage, and rent support Port operations. The project was undertaken as part of the Port's ongoing capital program.

The Skypass Bridge was funded through a combination of funds from state tax revenues and Port system user charges. The state provided funds through the Florida Seaport Transportation and Economic Development Program, Florida Department of Transportation funds, and a grant from the Florida Office of Trade, Tourism, and Economic Development. The bridge was planned as a toll-free facility, so funding needed to come from sources other than direct vehicle user charges. The Port's contribution from general enterprise revenues, although not a direct user fee, can be viewed as an indirect beneficiary charge, since improved access should benefit port users.

The Port leveraged general system revenues through the issuance of Public System Revenue Bonds to finance its $10 million share of project costs. State tax dollars were contributed through various grants, providing an additional $19.6 million. The Port also provided $100,000 of contributed capital (also from system revenues) to round out the proceeds for the project.

port-related dedicated taxes may be favored by policymakers as maintaining a link between the beneficiaries of the infrastructure and the funding source. However, in many cases—especially at the local level—the dedicated tax is of a general nature. For example, the Port of Seattle imposes an ad valorem real estate tax to support debt service on its general obligation port bonds and fund capital costs for certain projects; counties in California have the option, subject to voter approval, of assessing increments of 0.5% sales excise taxes as dedicated revenue streams for local transportation projects. In these cases, the link between the beneficiaries and the pledged revenue stream is more tenuous.

A value capture tax refers to the use of special taxing or assessment districts to capture the enhanced value of real estate resulting from investing in adjacent infrastructure improvements. The revenues are used either to fund projects directly or, more commonly, to pay debt service on bonds issued to fund such projects. The most common applications are tax increment financing and special assessment districts. Tax increment bonds (also known as tax allocation bonds) are used to fund infrastructure improvements to support economic development within a defined district. The incremental increase in property tax revenues (over and above the pre-existing level of tax receipts) that results from the higher value of new development is used to pay debt service on the bonds. Special assessment bonds are backed by a higher tax rate (essentially a real estate tax surcharge) imposed on property within the vicinity of a new infrastructure improvement funded from bond proceeds. The special assessment surcharge is intended to recapture from property owners a portion of the benefit their property receives (improved accessibility or enhanced services and amenities) from the infrastructure investment.

15.4.2 User Charges

Intermodal projects can be backed by user charges collected by public agencies with multiple facilities (public enterprises), corporate-wide pledges, or project-specific tolls or fares.

The system revenues of a *public enterprise* are receipts derived from fees, tolls, rents, etc., paid by users of the agency's services or facilities. For example, a regional transportation authority may own multiple toll facilities (Port Authority of New York & New Jersey) or multiple marine terminals (Port of Long Beach) that operate as a system and generate revenues for the enterprise. The source of the revenue funding the pay-as-you-go outlays or the debt service on bonds is not linked to any single facility. Public enterprises also may have access to general tax support, either in limited amounts, as with the ports of Tacoma and Seattle (Washington) or in unlimited general tax support, as with the Port of Houston (Texas) and Port of Portland (Oregon).

Similarly, a *corporate obligation* may be thought of as a private-sector, system-wide pledge of user charges the company generates from operating both the intermodal facility and its other business activities. In making its investment decision, a company such as Maersk or UPS will perform an internal analysis to determine if a proposed facility will provide a favorable corporate return on investment. If the company issues debt obligations to finance the project, the bonds may be secured by the company's general credit, rather than revenues of the project alone.

Project-based user charges are the funding source for "project financings"—financial structures using nonrecourse debt (i.e., debt that is not secured by a broader governmental or corporate pledge) backed by a net revenue pledge associated exclusively with the facility being financed. The Port of Seattle's Terminal 18, the CenterPoint Intermodal Center, and the Alameda Corridor each are supported largely or entirely by rent or fees charged to users of the financed project's infrastructure.

15.5 Financing Mechanism

Because intermodal projects tend to be highly capital-intensive and the entire facility must, in most cases, be completed before it can begin to generate user charges, a pay-as-you-go funding approach typically is not practicable. In addition, waiting to accumulate sufficient revenues to commence construction subjects the project to cost inflation. Therefore, once the potential sources of funding have been identified, project sponsors typically seek to identify the most cost-effective financing mechanism to capitalize the revenue stream into an initial amount.

Capitalization involves obtaining spendable proceeds for capital outlays through equity or debt investments based on the future revenue streams or creditworthiness of an enterprise. These financing instruments may be classified based on the type of proceeds employed (capital contributions, equity, or debt), the pledge of security backing the debt, and the sources of debt capital.

➤ Alameda Corridor Project

The Alameda Corridor Project consolidated 90 miles of surface branch rail lines into a high-speed, grade-separated freight rail connector, eliminating conflicts at more than 200 at-grade railroad crossings. The project links the ports of Los Angeles and Long Beach to rail yards in east Los Angeles with transcontinental rail corridors serving the rest of the nation.

The Alameda Corridor had a long list of stakeholders, including transportation agencies (the Port of Los Angeles, the Port of Long Beach, and the Los Angeles County Metropolitan Transportation Authority); the cities of Los Angeles and Long Beach, as well as numerous local communities along the route; rail carriers (Union Pacific and BNSF); and shippers, truckers, and others involved in maritime commerce in Southern California.

The cities of Los Angeles and Long Beach created a new special-purpose agency, the Alameda Corridor Transportation Authority (ACTA), to serve as the project sponsor, owner, and operator. ACTA was empowered to charge fees to railroads using the corridor and to issue debt backed by the revenues it collects. The project was undertaken on a stand-alone basis as the sole capital investment of the Authority.

The principal funding source was direct user charges to be collected by ACTA from the railroads (supporting approximately 70% of project costs), supplemented by federal, state, and local grant contributions (supporting 30% of project costs).

ACTA issued both taxable and tax-exempt debt to monetize $1.165 million of the future funding stream to be generated by income from railroad shipping fees. Another $400 million of the same funding stream was monetized through a loan from the US Department of Transportation and subsequently refinanced with tax-exempt debt proceeds. Tax-exempt governmental purpose revenue bonds financed those portions of the project deemed to benefit the general public (such as overpasses crossing the Corridor), and taxable private activity bonds were used to finance those portions deemed to primarily benefit the railroad carriers and their customers. (*1,2*)

15.5.1 Type of Proceeds

Accessing upfront capital for a project is achieved through the use of financing tools: (a) contributed capital, in the form of public grants or private contributions, (b) equity investment, and/or (c) leveraging a funding stream using some form of debt (bonds, loans, capital leasing, vendor financing, and so forth).

Contributed capital refers to money given to a project without any associated direct monetary payback; the contribution is not in exchange for an equity stake in the project or any contractual commitment from the project to provide a return on investment. Both the public sector and the private sector may contribute capital to a project. Governmental grant agreements provide the project with resources generated from federal, state, or local tax dollars, with no repayment obligation and generally no ownership interest by the grantor in the facility being financed. Rather, the public subsidy is justified by the spillover benefits the investment will provide to the general public. Private-sector contributions similarly provide funds to a governmental project sponsor (often as part of a "matching requirement" for the sponsor to obtain government grants), with no explicit financial return or ownership interest in the assisted project. The private donor is willing to make a strategic contribution to the project, such as donating right-of-way or funding a new interchange adjacent to its intermodal facility, because it believes the access project will confer some operational—and ultimately, financial—benefit to the company's business.

The form of private contribution described above is distinguished from an equity investment, in which a private-sector entity acquires an ownership interest in the financed facility or its revenue stream, based on the expectation of a direct return of project cash flows and/or the receipt of tax benefits (depreciation deductions and other offsets to taxable income). The APM and CenterPoint project sponsors both invested equity as part of the capital sourcing for financing their facilities, with the expectation of realizing favorable returns from their financial interest in the completed facilities.

Debt encompasses any form of credit instrument for generating upfront proceeds against the promise of future repayments to the lender/investor. The most common debt vehicles are bonds and loans. Bonds are long-term borrowings that access the nation's capital markets. They generally are sold to multiple lenders or investors, often are rated by one of Wall Street's credit-rating agencies, and are intended to be "marketable" (liquid or salable in the secondary market after issuance and prior to stated maturity).

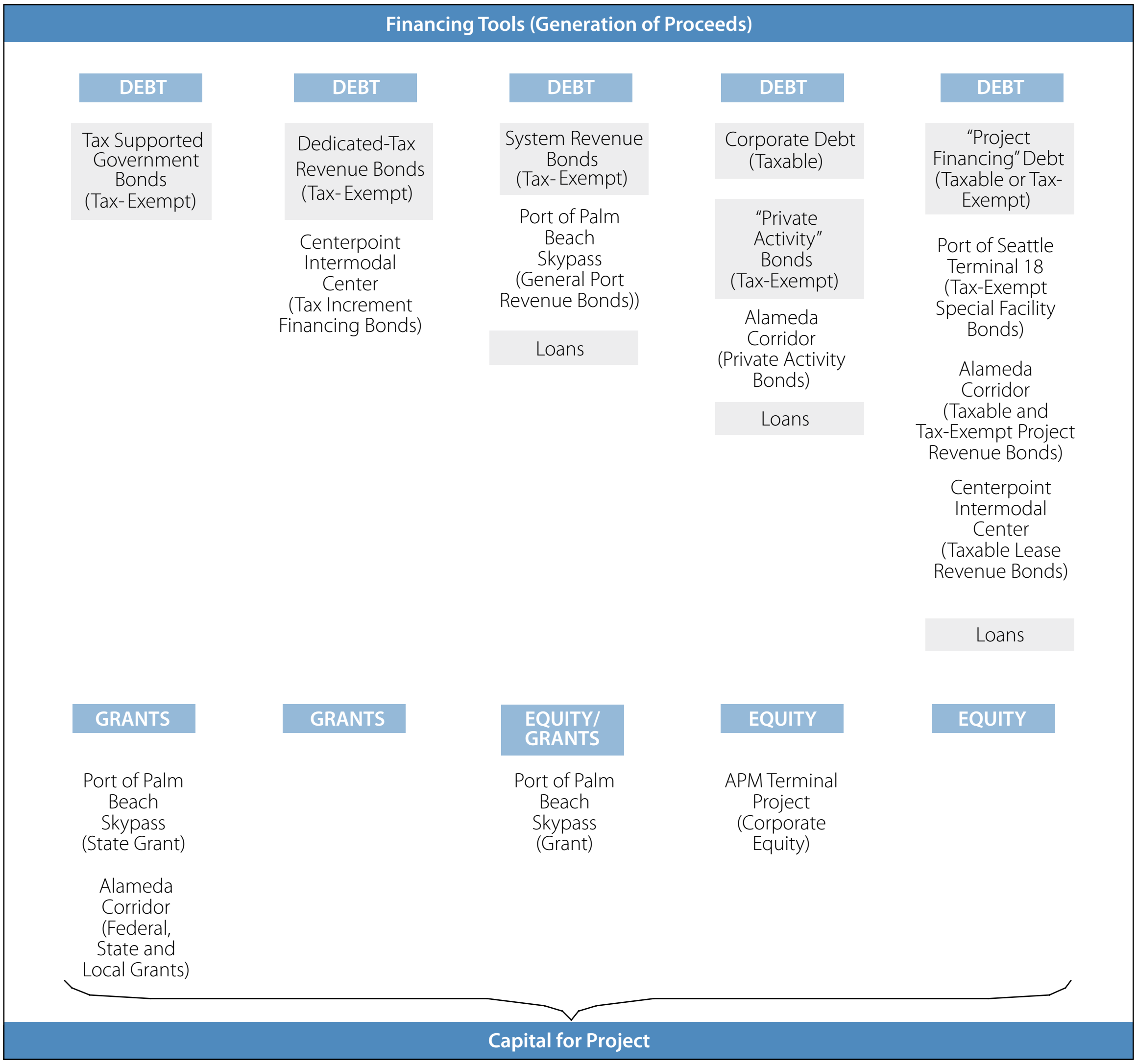
Loans generally can be described as credit agreements between the borrower and a single lender or limited number of lenders, typically a private placement with a private lending institution or government organization. Loans tend to be illiquid; in contrast to a bond, the lender has no assurance of being able to sell its loan to another investor or lender prior to its stated maturity.[2] Unlike the real estate sector, where the collateral value of the financed asset figures prominently in a lender's credit decision, the creditworthiness of most infrastructure debt is based largely on cash flow valuation—the predictability of the pledged repayment sources—due to the limited alternative use of the special-purpose transportation asset being financed.

15.5.1.1 Pledge of Security Backing Debt

Debt can be classified according to its pledge of security for repayment or its source of capital. The sources of repayment for debt or return on equity align closely with the funding streams described in the previous section. (Figure 15-6)

2 A portfolio of small, illiquid, and nonrated loans with similar characteristics potentially can be pooled into marketable "asset-backed" investment-grade securities and sold into the capital markets. However, the turmoil in the credit markets commencing in 2007 demonstrated that pooling—even by the nation's largest and most sophisticated financial institutions—does not eliminate the default exposure associated with high-risk underlying loans.

Figure 15-6 Project financing tools



15.5.1.1.1 Tax-Supported Bonds

Tax-supported bonds may be classified as general obligation bonds, grant-backed bonds, and special revenue bonds:

General obligation bonds are issued by a governmental entity and backed by its full faith, credit, and taxing power. At the local level, general obligation bonds are typically backed by a pledge of unlimited ad valorem real estate taxes.

Grant-backed bonds or Grant Anticipation Revenue Vehicles (GARVEEs) are bonds repayable from the issuer's receipt of federal grants over a multiyear time period. These can be considered a form of tax-supported debt in that the intergovernmental grants securing their repayment are ultimately derived from the Highway Trust Fund (public tax dollars).

➤ Port of Seattle Terminal 18 Expansion Project

The Port of Seattle Terminal 18 (T-18) project is an expansion of an existing maritime container terminal in the South Port area. The project increased berth capacity, doubled the size of the terminal, and substantially improved intermodal rail capacity by enabling maritime cargo to be loaded directly onto railcars. Two freight rail carriers serve Terminal 18—Union Pacific and BNSF.

The principal stakeholders are the Port of Seattle (a public agency with five elected board members from King County) and Stevedoring Services of America, Inc, a privately held company that owns SSA Terminals, LLC, the terminal tenant.

The project was sponsored by the Port of Seattle, but was advanced separately from the rest of the Port's capital program, which is supported by system-wide revenues from user charges and a dedicated portion of property tax revenues with King County.* Due to the large project size and limitations on the Port's general debt capacity, Terminal 18 was structured with stand-alone project financing.

The improved terminal facilities are being leased over 30 years to SSA Terminals, LLC, a private terminal operator, generating a dedicated revenue stream to support the project.

This funding source was monetized using a $300 million tax-exempt, special facility revenue bond issued through the Port on a conduit basis. The bonds are not a liability of the Port, but rather are limited obligations secured solely by the lease revenues from SSA Terminals, and the associated debt does not appear on the balance sheet of the Port. (*5*, p. 41)

* The Port is authorized under Washington State law to levy property taxes within King County for general Port purposes at a rate not to exceed 45 mills. In addition to borrowing against its net income or general revenues, the Port can issue general obligation debt backed by the full faith and credit of the Port.

Dedicated tax special revenue bonds are backed by a fixed, dedicated tax stream, such as an increment of a sales tax (examples include local option sales tax revenue bonds in California counties or special obligation gas tax revenue bonds in Massachusetts). Typically, special revenue bonds are backed by a designated revenue source that is independent of the facility being financed. For this reason, the borrower can give a "gross" pledge (before funding operations) of the first revenues received to secure debt service, since the annual revenue stream is not dependent on funding operations of the facility itself. The rate or level of the dedicated tax usually is fixed legislatively (not subject to adjustment in the event of shortfalls).

A new form of tax-supported debt that has emerged in recent months is "availability payment" bonds. These are bonds issued for a project, such as a bridge or highway, being developed and managed by a private concessionaire. The facility itself may or may not be tolled; the government's obligation to make payments to the private operator for operations and debt service is subject to the project meeting certain predefined performance standards (such as being fully available for public use). In this manner, this debt instrument combines elements of tax-supported borrowing with project finance, as described below.

15.5.1.1.2 User Charge Debt

User charge debt may be categorized as system revenue bonds, corporate bonds, or project financing bonds.

System revenue bonds refer to bonds backed by the net revenues generated by a public enterprise with either an existing, large-scale, income-producing asset (beyond the new facility being financed) or multiple facilities. The revenue pledge for system revenue debt typically is "net"; that is, operating and maintenance costs must first be paid if the enterprise is to continue generating revenues. The consolidated bonds of the Port Authority of New York & New Jersey are secured by net revenues from the authority's entire portfolio of transportation- and commerce-related assets, which includes three metropolitan New York–New Jersey airports, an interstate transportation network (tunnels, bridges, terminals, and the Port Authority Trans-Hudson transit line), and various marine terminals. Proceeds from these bonds are used to support capital improvements. (*4*)

Corporate bonds are supported by the sponsoring company's general balance sheet. The company's credit may be pledged to secure bonds issued directly by the company or issued indirectly through a financing conduit under a lease agreement, corporate guarantee, or similar pledge of company resources. For example, the Port of Seattle issued special facility bonds for the expansion of its Terminal 18; these bonds are not secured by the Port's general resources but effectively are a corporate credit of SSA Terminals, its tenant and the operator of the terminal.

Project financing bonds refer to borrowings by a legally independent entity, with repayment backed solely or predominantly by the net revenues of the particular facility being financed. It is often called nonrecourse or stand-alone debt, meaning the project's bond holders cannot look beyond the facility and its related revenues for security to repay debt service. Project financing can be used in lieu of system revenue bonds or corporate-backed bonds to insulate the sponsoring entity against the risks associated with the project failing to cover its costs, since the bondholders have no claim on the governmental sponsor or corporate sponsor. The single-purpose financing conduits established to issue debt for such projects tend to be highly leveraged; that is, a majority of the needed capital is obtained from debt proceeds, as opposed to equity or contributed capital.

15.5.1.2 Sources of Debt Capital

Debt can also be classified by the *source of the capital* being accessed. Common sources of debt capital include the tax-exempt bond market, the taxable (corporate) bond market, federal credit programs, and state infrastructure banks.

15.5.1.2.1 Tax-Exempt Bond Market

The interest income on bonds issued for public purposes by a state or local governmental entity generally is exempt from federal income tax (and state/local tax in the jurisdiction in which issued). Tax-exempt municipal debt is further differentiated as follows:

- *Governmental purpose bonds,* for federal tax purposes, are debt obligations with minimal private participation in the use of proceeds and the source of security for repayment.
- *Qualified private activity bonds* are, for federal tax purposes, a special class of tax-exempt bonds available for financing projects where there is private participation in a project that Congress has determined provides public benefit,

thus justifying tax-exempt status.[3] Most bonds that involve private participation may not be issued on a tax-exempt basis; the exceptions are those that meet one of the enumerated "exempt facility" categories. In the transportation sector, Congress has created specific exceptions allowing for qualified private activity bonds to finance corporate-related seaport and airport facilities (no federal volume cap on annual issuance), and up to $15 billion of highway and intermodal rail-truck facilities, with the secretary of transportation selecting the projects. Private activity bonds historically had required a slightly higher interest rate than governmental purpose bonds because the interest earned on private activity bonds is subject to the alternative minimum tax (AMT), making them somewhat less attractive to investors. The American Recovery and Reinvestment Act of 2009 (Recovery Act) waived the AMT requirement for bonds issued through year-end 2010, putting private activity and governmental purpose bonds on a more equal footing.

15.5.1.2.2 Taxable Debt Sources

Taxable debt typically refers to publicly issued debt obligations sold into the corporate bond market. But it also includes syndicated bank loans arranged through private placement. In addition, taxable debt describes other obligations such as vendor financing and capital leases, where the interest income is taxable to the lender or lessor. As part of the Recovery Act, Congress established a new form of federally subsidized taxable debt—Build America Bonds, under which the Treasury Department subsidizes 35% of a governmental issuer's interest expense on taxable bonds through a direct subsidy to the governmental agency. For certain other volume-cap-constrained programs in the energy, education, and conservation sectors, Congress has authorized federal tax credits designed to cover up to 100% of the interest cost of borrowing.

15.5.1.2.3 Federal Credit Programs

Government lending is available via federal credit programs and state infrastructure banks, where lendable funds are provided from public tax dollars. Congress has established two major federal-level credit assistance programs for surface transportation: the Transportation Infrastructure Finance and Innovation Act (TIFIA) and the Railroad Rehabilitation and Improvement Financing (RRIF) program. Although loan guarantees and lines of credit are offered, the most common form of credit assistance is the direct loan, where the Treasury Department lends directly to project sponsors at a rate set at the Treasury's cost of funds.

As of this writing, Treasury rates are competitive with tax-exempt rates for most issuers, making Treasury loans a very attractive source of financing. Fed-

3 Under Section 141 of the Internal Revenue Code an issue is a private activity bond if more than 10% of the proceeds of the issue are used by a private business and more than 10% of the debt service is supported by private business payments. For example, a marine terminal leased to a private operator, or an air freight cargo or intermodal yard used by a private-sector carrier and payable from rental payments, would constitute a private activity.

eral credit also has the advantage of being prepayable at any time, as well as of having minimal transaction fees. Although originally intended to fund projects backed by user charges, TIFIA also has been used for tax-backed transportation borrowings.

15.5.1.2.4 State Infrastructure Banks

In 1995, Congress authorized states to establish their own lending programs with federal grants, under the State Infrastructure Bank program. Nearly 40 states have established direct lending programs where they capitalize (provide lendable funds for) a state entity that extends loans at below-market rates to transportation project sponsors. In most states, these infrastructure banks are funded with modest amounts of federal-aid apportionments, although banks in several states have issued their own tax-exempt debt in order to fund "downstream" loans to projects.

15.6 Industry Overview and Findings

Table A-1 at the end of this chapter lists 35 projects identified as "freight" or "cargo access" projects that are intermodal in nature (handling freight transfers from rail to truck, ship to rail, air to truck, etc.), as opposed to single-mode capacity expansion projects. Each of these projects either is currently operating or has its financing arrangements in place. No proposed projects or projects in the early development stages have been included, since final decisions have not been made on funding sources and financing approaches.

The 35 projects represent some $7.3 billion of capital investment over the past decade. The projects are categorized in Table 15-2. In terms of modal split, 41% of the projects (and 72% of the capital investment) involved port-related intermodal facilities; 45% of the projects (26% of the capital investment) involved rail-related facilities; and 14% of the projects (2% of the capital investment) were related to air-cargo facilities. (Figure 15-7)

Breaking the data down a different way, only 37% of the projects (28% of the capital investment) were terminal facilities. The balance (63% of the projects and 72% of the capital investment) involved ground access facilities.

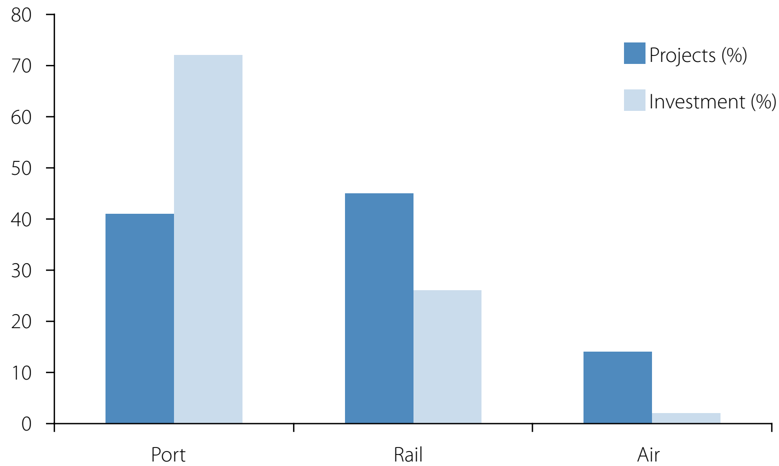
Twelve of the projects represent discrete surface access and terminal facilities for six larger projects. While the terminal and access components typically are delivered in tandem, they generally rely on differing funding sources and financing mechanisms, thus justifying their treatment as separate projects.

Access projects tend to be smaller and more numerous. The median dollar size of all the projects studied was approximately $33 million. The median dollar size

➤ **Table 15-2** Profile of intermodal projects studied

Type of Project	Quantity	Value ($ millions)
Port terminal	3	854.0
Port access	11	4,414.2
Air cargo terminal	3	141.5
Air cargo access	2	31.1
Rail-truck terminal	6	1,013.6
Rail-truck access	5	76.6
Rail capacity	5	767.6
TOTAL	35	7,298.6

➤ **Figure 15-7** Intermodal project list, by mode



of access projects was $29.5 million, while the median for terminal projects was more than $90 million.

The public sector tends to assume more of the organizational responsibility (sponsorship) for access projects, in contrast to terminal projects, which more often are sponsored by private entities. All but one access project was sponsored by an existing public-sector entity, whereas approximately 70% of terminal projects were privately sponsored.

Not surprisingly, there is a parallel trend for funding sources. On average, terminal projects received less than 10% of their funding from tax-based sources; more than 90% was derived from user charges. In contrast, funding for access projects was derived predominately from taxes (63%), with the remainder (37%) coming from user charges (rents or fees charged by public enterprises or private companies).

The vast majority of terminal and access projects were funded as "system" credits, secured by the backing of a public enterprise with multiple revenue sources, or by the general credit of a corporation involved in interstate commerce. Most projects (32 of 35) were backed by system-wide revenues, rather than being secured solely by the revenues from the project itself.

The 35 projects used a wide array of debt instruments and financing mechanisms. The limited number of projects and their diverse character hinders making broad generalizations about the financial strategies for projects, but certain observations can made. Less than half of the projects (14 of the 35) appeared to use debt financing secured by the project's identified tax or user-charge revenue streams. The majority of the projects relied on pay-as-you-go funding, using governmental grants, corporate contributions, and current revenues. Of the approximately $3 billion of debt issuance, half was sourced through the tax-exempt bond market, and the balance was financed through

➤ CenterPoint Intermodal Center Project

The 2,200-acre CenterPoint Intermodal Center consists of warehouse and distribution space (ultimately up to 12 million square feet) and an intermodal facility located 40 miles southwest of Chicago, at the site of the former Joliet Arsenal. The Center is anchored by the 770-acre BNSF Logistics Park, a new rail-truck transfer facility.

Private-sector stakeholders are the project sponsor (CenterPoint Properties Trust), BNSF Railway, and various corporate tenants. Public-sector stakeholders include the Illinois Department of Transportation and various local municipalities, including the village of Elwood, Illinois. Other organizations with ties to the site include the US Army, since the site was a former military base, and the Illinois Department of Natural Resources, as the site contained open space important to regional preservation efforts.

CenterPoint Properties Trust is a privately held real estate investment trust with a portfolio of 23 business park properties in and around Chicago. The Trust developed the CenterPoint Intermodal Center as part of its industrial real estate investment program to expand its business and generate favorable returns for its investors. CenterPoint owns the facility and leases it to various commercial tenants, such as Walmart and Georgia-Pacific, as well as BNSF.

Revenue for project funding came primarily from the general revenues of CenterPoint and the anticipated lease revenues from the developed properties. Tax-based revenues were also made available for the highway transportation and public infrastructure components of the project. The project received state and federal grants totaling more than $35 million to build a new highway interchange at Interstate 55 adjacent to the facility. The project received indirect public funding through the tax-advantaged and subsidized financing associated with the site's designation as an Enterprise Zone and a Foreign Trade Zone.

Tax increment financing bonds were issued by the local municipality of Elwood, Illinois; proceeds were used to reimburse CenterPoint, the developer, for the costs associated with basic water and sewer infrastructure at the project site. (*2*)

the taxable debt market or with federal (and to a limited extent, state) loan programs. About a third of the debt was backed by dedicated taxes, with the remainder secured by project user charges or by corporate revenues. The range of debt instruments employed included governmental purpose tax-exempt bonds, private activity tax-exempt bonds, taxable revenue bonds, federal credit assistance through two programs (TIFIA and RRIF), state credit assistance, and leveraged leasing. Half of the projects also drew upon private equity investment and contributed capital to round out the financing sources.

15.7 Conclusion

Intermodal freight projects comprise a diverse array of terminal improvements, local access connections, and longer surface transportation corridors that facilitate the movement of goods by land, air, and sea. Although this chapter focused specifically on intermodal projects, these facilities cannot be viewed in isolation, since they are inextricably related to the trucking, railroad, aviation, and maritime companies using them. Given the wide variety of modes, stakeholders, and organizational structures, the approaches used to advance major intermodal projects tend to be as varied as the projects themselves.

Nevertheless, by applying the taxonomy presented in this chapter to the approximately three dozen intermodal projects that have been financed to date, it is possible to draw several conclusions concerning the financial strategies employed.

Types of projects—Most of the capital investment, in terms of both number of projects and dollar value, is in ground access infrastructure, as opposed to terminal facilities.

Project sponsors—Existing governmental entities have served as project sponsors for more than two-thirds of the projects, the majority of which were access projects. Private corporations served as project sponsors for about one-quarter of the projects—all of which were terminal facilities. Special-purpose entities served as project sponsors for only three projects. It may well be that a complicated project, such as the Chicago Region Environmental and Transportation Efficiency (CREATE) Program, a highly-complex and partially completed series of projects involving six rail carriers and several public stakeholders, would benefit from the establishment of a special-purpose entity charged with bringing the project to fruition.

Capital programs—The overwhelming number of facilities were financed as part of a larger capital program of the sponsor, rather than on a one-off, stand-alone basis.

Funding sources—Most of the projects (60%) utilized a combination of general tax support and some form of user charge or corporate backstop. All of the access projects drew on general or dedicated taxes, and all of the terminal projects were supported at least in part by user charges or corporate pledges. Private-sector participants tend to bear a greater share of funding for terminals, whereas the public sector typically provides more of the funding for access projects. This pattern supports the conclusion that capital investments generating benefits principally to the community at large rather than to the carriers (such as grade separation access projects that reduce local congestion and enhance safety), warrant a higher proportion of public (tax supported) funding. Terminal facilities, on the other hand, whose principal benefits are to the private operators and carriers, rely more heavily on private (corporate and user charge) revenue streams.

Financing mechanisms—The financing tools closely parallel the underlying revenue streams. Most of the projects relied on governmental grants, contributed capital, or equity investment for at least some portion of their financing sources. Only 40% of the projects used debt proceeds that could be identified as being directly associated with the project. The wide range of debt instruments used—governmental purpose tax-exempt bonds, tax-exempt private activity bonds, taxable debt, leveraged leasing, and federal credit loans—reflects the variegated nature of the projects.

In summary, an intermodal project's financial strategy, as defined by its organizational structure, designated funding sources, and capital-raising approach, reflects the distribution of public and private benefits among the users of the facility, neighboring communities, and the public at large. The greater the public spillover benefits, the larger is the share supported by the public sector. Recent deterioration in the credit markets may make it more difficult for projects backed by new revenues streams to access the capital markets without some form of backstop by either public or private sponsors. But as additional intermodal freight projects are implemented to meet the nation's growing need for efficient goods movement, our understanding of the advantages of using various approaches should correspondingly increase.

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Table A-1 Survey of Intermodal Freight Projects

Project Name	State	Project Sponsor	Type of Project	Amount ($ mils.)	% Tax-Supported	% User-Charge Funded	Private Participant
Little Rock Port Authority Slackwater Harbor Improvements	AK	Little Rock Port Authority	Road and rail access to port	$11.80	100%	0%	
Alameda Corridor	CA	Alameda Corridor Transportation Authority	Rail access to ports	$2,438.00	36%	64%	Union Pacific, Burlington Northern Santa Fe
Stockton Airport Freight Terminal—airport and roadway access improvements	CA	San Joaquin Co.	Air and road access to airport	$1.74	96%	4%	Farmington Fresh
Stockton Airport Freight Terminal—terminal and cargo handling facility	CA	San Joaquin Co.	Air frieght terminal facility	$6.50	0%	100%	Farmington Fresh
Denver International Airport Cargo Facility	CO	WorldPort at DIA LLC, Lehman Bros.	Air frieght terminal facility	$100.00	0%	100%	WorldPort at DIA LLC, Lehman Bros.
Shellpot Bridge Replacement	DE	DE DOT	Rail access to port	$13.90	36%	64%	
Palm Beach Skypass Bridge Construction (port access)	FL	Port of Palm Beach	Road access to port	$29.70	66%	34%	
Bensenville Rail Yard Improvements	IL	Chicago Area Trans. Study	Rail access to rail yard	$35.00	6%	94%	Canadian Pacific Railroad
BNSF Logistics Park at CenterPoint Intermodal Center at Deer Run	IL	CenterPoint	Rail-truck facility	$90.20	0%	100%	CenterPoint, BNSF
CenterPoint Intermodal Center at Deer Run	IL	CenterPoint	Truck distribution facilities	$600.00	21%	79%	CenterPoint, BNSF, other private tenants
CenterPoint Intermodal Center at Deer Run - I-55 Interchange and access improvements	IL	IL DOT, Local municipalities	Road access to rail-truck and truck distribution facilities	$36.30	100%	0%	CenterPoint
Chicago Area Consolidation Hub—access	IL	IL DOT	Road access to truck distribution center	$27.40	64%	36%	UPS, BNSF
Chicago Area Consolidation Hub—intermodal facility	IL	BNSF	Rail-truck facility	$70.00	0%	100%	UPS, BNSF
Chicago Region Environ-mental and Transportation Efficiency (CREATE) Program (IL)	IL	IL DOT, City of Chicago	Rail access improvements	$442.00	52%	48%	UP, BNSF, NS, CP, Canadian National, CSX
Kedzie Ave Access Road/ Stoplight (hwy access to BNSF Corwith rail yard)	IL	City of Chicago DOT	Road access to rail yard	$4.70	100%	0%	BNSF
Riverport Railroad Rehabilitation and Yard and Transload Facilities Construction	IL	Riverport RR	Rail yard/ transloadal facility	$5.50	0%	100%	Riverport RR

Table A-1, *continued*

Project Name	State	Project Sponsor	Type of Project	Amount ($ mils.)	% Tax-Supported	% User-Charge Funded	Private Participant
Rochelle Intermodal Center/ UP Global III	IL	Union Pacific	Rail-truck facility	$183.20	1%	99%	Union Pacific
Rochelle Intermodal Center/ UP Global III Access	IL	City of Rochelle, Union Pacific	Road and rail access to rail-truck facility	$7.60	57%	43%	Union Pacific
Port of South Louisiana Rail Spur Upgrade	LA	Port of South Louisiana	Rail access to port	$1.20	100%	0%	
Tchoupitoulas Corridor Improvements (Port of New Orleans Access)	LA	Port of New Orleans, City of New Orleans	Road access to port	$100.70	100%	0%	
Auburn Intermodal Freight Facility	ME	City of Auburn	Rail-truck facility	$4.70	79%	21%	St. Lawrence and Atlantic RRs
Rail Access to Luce County Industrial Park	MI	MI DOT	Rail access to rail-truck facility	$0.65	84%	16%	Sustainable Forest Products Inc, Canadian National Rail
Reno Transportation Rail Access Corridor (ReTRAC)	NV	City of Reno	Rail access improvements	$279.90	76%	24%	Union Pacific
PIDN—Albany Express Barge (Port of NY and NJ to Port of Albany)	NY	PANYNJ	Maritime access to port	$11.10	100%	0%	
Red Hook Container Barge, Port of NY/NJ	NY, NJ	PANYNJ	Maritime access to port	$58.80	100%	0%	American Stevedoring
Rickenbacker Intermodal Terminal—Part of Heartland Corridor Project	OH	Columbus Regional Airport Authority	Rail-truck facility, adjacent to airport	$64.70	47%	53%	Norfolk Southern
Columbia Slough Bridge to Intermodal Yards	OR	Port of Portland	Rail access to port	$6.00	100%	0%	Union Pacific and BNSF
Air Freight Regional Hubbing Facility	SC	Richland-Lexington Airport	Air and road access to airport	$29.35	100%	0%	UPS
Air Freight Regional Hubbing Facility	SC	Richland-Lexington Airport	Air frieght terminal facility	$35.00	0%	100%	UPS
Cooper River Bridge Replacement	SC	SC Ports Authority	Road access to port	$667.00	100%	0%	
Maersk Terminal at Port of Hampton Roads	VA	Maersk	Port freight terminal	$453.00	1%	99%	Maersk
Heartland Corridor—vertical clearance and rail relocation	VA, WV, OH	Eastern Federal Lands Highway Division	Rail access to ports and rail-truck facilities	$218.10	80%	20%	Norfolk Southern
Freight Action Strategy (FAST) Corridor	WA	Puget Sound Regional Council	Road and rail access to port	$863.90	97%	3%	UP, BNSF
Hyundai Terminal at Port of Tacoma	WA	Hyundai, Port of Tacoma	Port freight terminal	$101.00	16%	84%	Hyundai, Port of Tacoma
Port of Seattle Terminal 18 Expansion	WA	Port of Seattle	Port freight terminal	$300.00	0%	100%	American Stevedoring
Total				**$7,298.64**			
Median $ Size of Projects				**$36.30**			

16

Congested Networks

Lance R. Grenzeback and Richard A. Margiotta

16.1 Introduction

The US intermodal freight transportation system consists of four major elements: the interstate highway system, which serves intercity truck moves; the metropolitan highway networks, which serve local and regional freight distribution; the transcontinental rail network; and the ports, rail terminals, and distribution centers that are the interchange points in the freight network. These freight transportation networks link producers and consumers across the United States, providing the access to resources, labor, and markets that is essential to economic activity and development. The national connectivity provided by the interstate highway system is just as important today as it was in the 1950s and 1960s when Congress debated and authorized the interstate highway program. And given emerging concerns about energy security, climate change, and global competitiveness, the transcontinental railroad system also provides crucial connectivity.

However, the connectivity of the nation's highway and rail systems—the ability to move freight quickly, cost effectively, and reliably from region to region and across the country—has not kept pace with population and economic growth. The growth in demand for freight transportation is pressing the capacity of the freight transportation system. The resulting congestion is driving up logistics costs and undermining the reliability and connectivity of freight movements, which are essential to the nation's economic well-being.

This chapter looks first at how congestion is defined and measured. It then describes the role of freight transportation in the economy and expected growth in demand for freight transportation. It reports on the deteriorating productivity of freight transportation networks and the increasing concern

Reprinted from *Intermodal Transportation: Moving Freight in a Global Economy.*

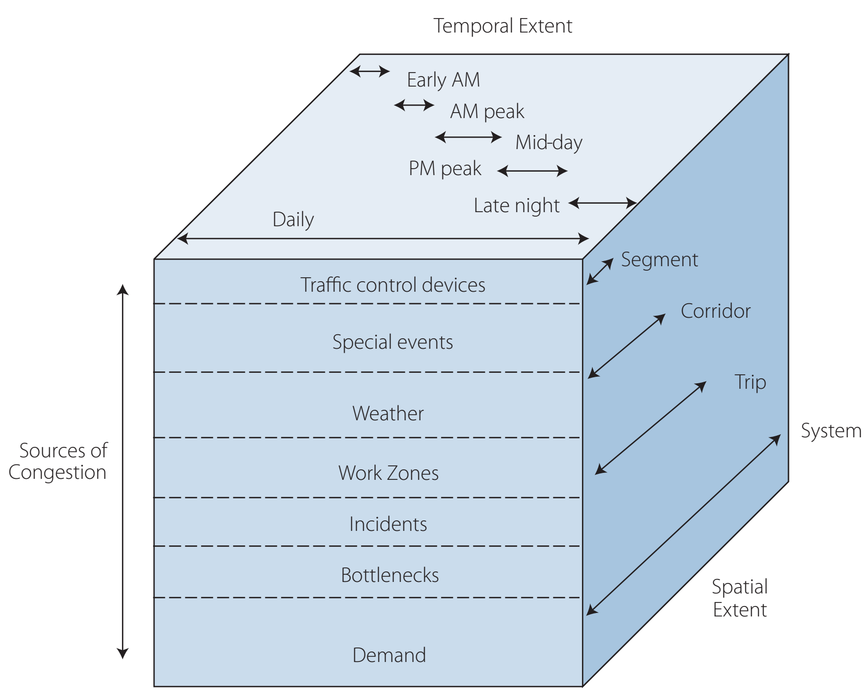
among businesses and industries that congestion will drive up logistics costs and undermine future economic productivity, international competitiveness, and economic growth. The final sections of the chapter map the known congestion and capacity problems of the highway and rail systems, describe the anticipated impact of future freight demand, and outline strategies for adding capacity and reducing the impacts of congestion.

16.2 Measuring Congestion

Congestion occurs when the number of vehicles traveling on a roadway exceeds the physical throughput capacity of the roadway or the number of trains on a rail line exceeds the capacity of the tracks. Congestion is typically measured by vehicle-hours of delay compared with travel under uncongested, free-flow conditions. The other dimensions routinely used to describe congestion are the source of the congestion, temporal duration, and spatial extent, as illustrated in Figure 16-1.

Variations in the location, intensity, and duration of congestion are major determinants of travel time and travel-time reliability. Travel-time reliability is especially important because if travel time cannot be predicted, then shippers

Figure 16-1 Dimensions of congestion



SOURCE: *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation*. (2).

and carriers must provide a buffer of extra time in their supply chains and distribution networks. This increases the cost of travel for motor carriers and railroads, and it indirectly increases the cost and risk to shippers and receivers who rely on just-in-time manufacturing and retailing deliveries to keep costs low and remain competitive in national and global markets.

Most measurements of congestion, travel time, and travel-time reliability are indirect. The Texas Transportation Institute's (TTI) long-running series of annual urban mobility reports relies on the Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS) to track annual changes in daily traffic and the number of lanes on the nation's highways. Mathematical models are applied to the HPMS data to estimate congestion. More recently, highway agencies have begun to measure congestion directly by installing in-pavement and roadside detectors to measure traffic volumes and speeds at specific points on highway networks. Where detectors are spaced closely enough (less than a mile apart), travel times and congestion can be inferred for entire segments of roadway. In regions with a significant number of toll roads and bridges, some agencies have installed readers on toll and nontoll roads to detect the passage of toll-tag-equipped vehicles and use this information to calculate directly the vehicles' speeds and travel times between readers. And most recently, private-sector companies have been estimating and selling traffic volume and speed data for major metropolitan and interstate highways by compiling data from cooperating public and private truck fleets equipped with cell phones or satellite-based global positioning system (GPS) technology.

As yet, however, there is no comprehensive national estimate of congestion and its costs. The closest approximation is TTI's compilation of congestion estimates for 85 urban areas across the United States, which show that congestion has grown substantially over the past 20 years (Figure 16-2) and across all dimensions of congestion (Figure 16-3). TTI reports that highway congestion in urban areas in 2007 created a $78 billion annual drain on the US economy in the form of 4.2 billion lost hours and 2.9 billion gallons of wasted fuel—the equivalent of 105 million weeks of vacation and 58 fully loaded supertankers.[1] *(1)*

Consensus-based estimates developed for FHWA suggest that on a national basis, 40% of roadway congestion is due to bottlenecks, 25% to traffic incidents, 15% to bad weather, and the remainder to maintenance and other events, as shown in Figure 16-4. *(2)*

The TTI reports capture the annual cost of congestion to automobiles and trucks traveling in the 85 urban areas, but the reports do not separate out the

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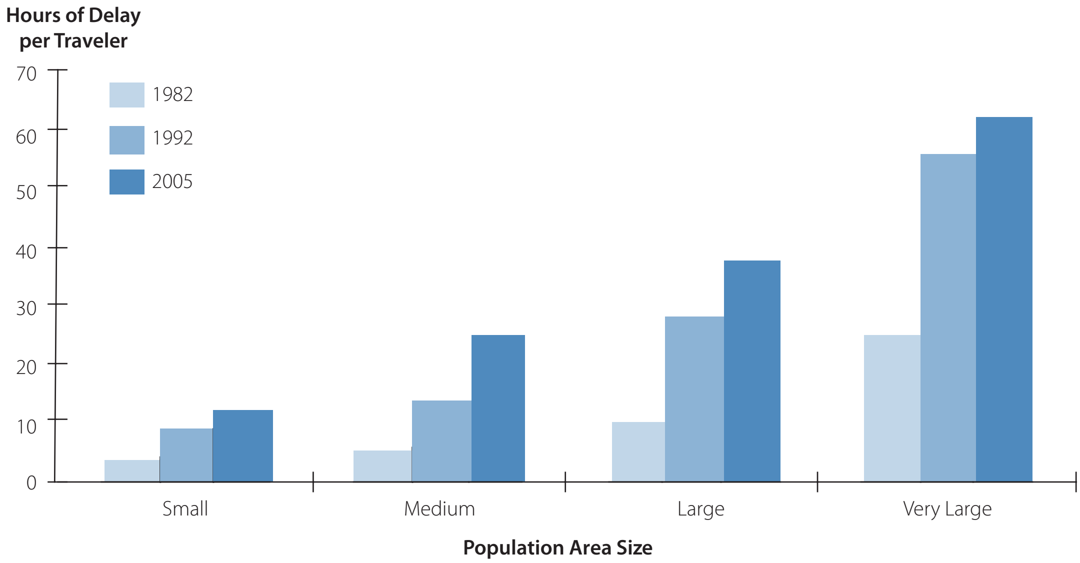
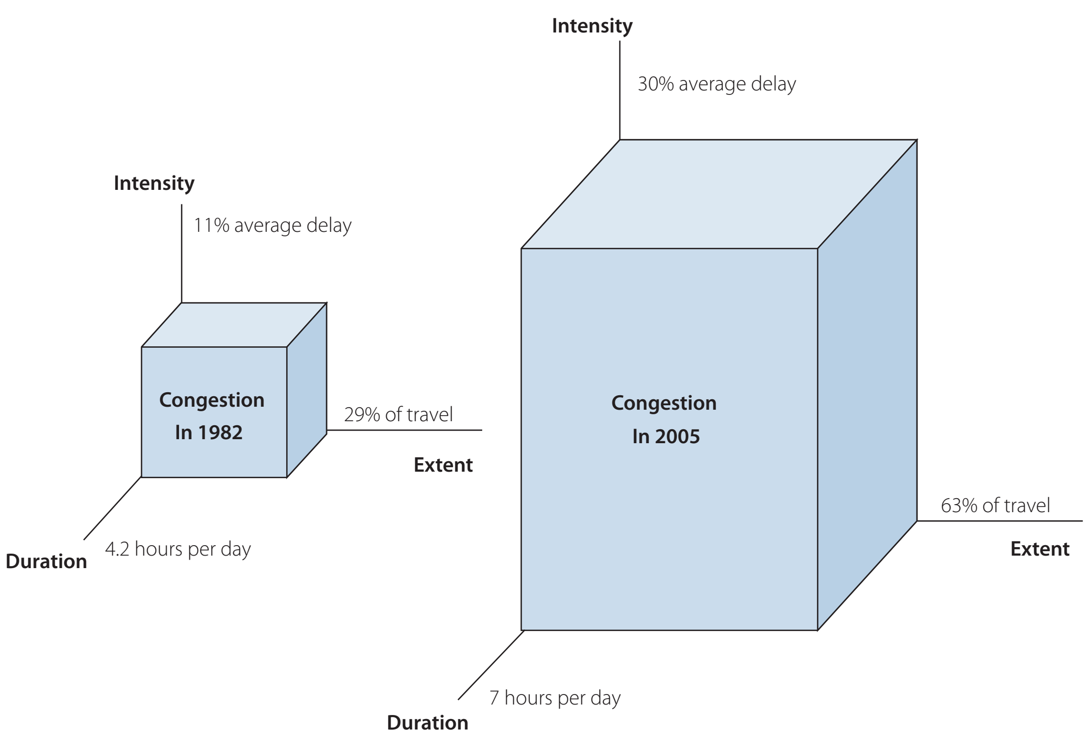
1 The TTI *2009 Urban Mobility Report* (which documents conditions through 2007) shows a slight decrease in 2007 congestion levels from 2006. It is likely that 2008 congestion levels will be lower than 2007, based on the downturn in economic activity. The link between travel and economic conditions has been observed before, as in the decrease in vehicle miles traveled during the 1982–83 recession. As economic growth occurs, congestion and travel are also expected to increase.

Figure 16-2 Congestion in US cities—1982, 1992, and 2005



SOURCE: *2007 Annual Urban Mobility Report.* (1)

Figure 16-3 Congestion has grown in all dimensions

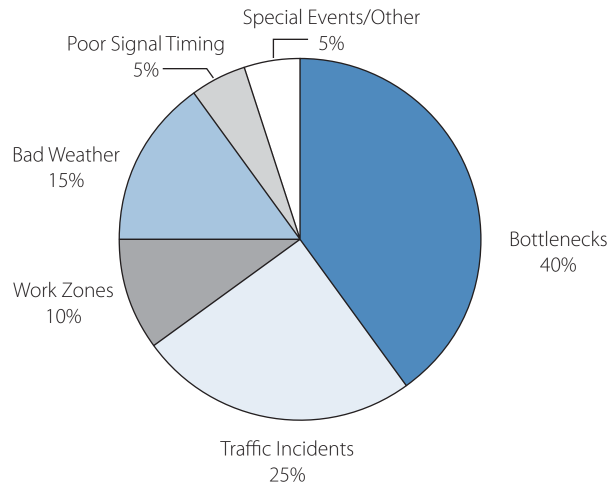


SOURCE: *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation.* (2)

congestion impacts that accrue to freight trucks. Nor are there comprehensive estimates of the total cost of congestion on the highway freight network or the rail freight network. However, research sponsored by FHWA, the American Association of State Highway and Transportation Officials (AASHTO), the Association of American Railroads (AAR), the US Chamber of Commerce, and others has begun to piece together a partial picture of the impact of congestion on the freight networks.

The next sections draw on this literature to describe the role of freight transportation in the US economy, the projected demand for freight transportation, and anticipated impact of increased congestion on logistics costs. Subsequent sections describe the congested freight networks.

Figure 16-4 Estimated sources of US highway congestion



SOURCE: *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation.* (2)

16.3 Freight Transportation and the Economy

Freight transportation is vital to the US economy. It is a $1.2 billion industry, generating 8% of jobs and accounting for 9% of the US economy, as detailed in Table 16-1. More importantly, it provides the equipment and services that support businesses and industries in agriculture and natural resources, manufacturing, retail, and services. Transportation represents 7% of the value of output in the agriculture and natural resources sector, 4.7% in the retail sector, and 3.2% in the manufacturing sector. And in the rapidly growing services sector—which does not produce material goods but depends on expedited delivery services, reliable long-distance business travel, and cost-effective employee commuting—transportation is 1.8% of the value of output. Together these businesses and industries account for 84% of the US economy. *(3)*

Table 16-1 US gross domestic product in transportation and logistics industry

Industry	Gross Domestic Product	Share/Trend
Transportation	$363.7 billion	2.7% / steady
Warehousing	$34.0 billion (est.)	0.3% / increasing
Wholesale Trade	$788.7 billion	6.0% / increasing
Transportation/Logistics Sector	**$1,152.4 billion**	**9% of US economy**
US Total	**$13,246.6 billion**	—

SOURCE: Cambridge Systematics, Inc., calculations based on data from the US Bureau of Economic Analysis, Annual Industry Accounts, 2006.

16.4 Freight Transportation Demand

The demand for all modes of freight transportation is growing. The US economy is forecast to grow at a compound annual rate of 2% between 2005 and 2035. At this rate, the demand for freight transportation—measured in tons—is projected to increase by 38% by 2035. Although substantial, this rate of growth is lower than that experienced over the past 30 years, when the US economy grew at a compound annual rate of more than 3%.[2] The four major drivers of this increased freight demand are as follows:

1. Consumption (i.e., the purchase of goods by individuals, households, and government)—The US population reached 300 million people in 2006 and will reach 386 million by 2035.[3] A larger population will consume more food, clothing, and housing, all of which must be moved through the freight system.

2. Production (i.e., investment and the creation of goods by businesses)—Although the number of people employed in manufacturing is projected to decline, automation will increase manufacturing production and output, generating more manufactured products to be shipped by truck and rail.

3. Trade (i.e., the exchange of goods)—Trade is expected to grow faster than the economy as a whole. In 2005, the combined value of US imports and exports was equivalent to 28% of the real (i.e., adjusted for inflation) US gross domestic product (GDP). The value of US imports and exports is forecast to be equivalent to 57% of GDP in 2035.[4] This will intensify the flow of imports and exports moving through US ports and international trade gateways. Imports are expected to dominate trade flows, but exports will rise and fall as currency values shift, requiring freight transportation capacity in both directions.

4. Supply chain management (i.e., the movement and storage of raw materials, inventory, and finished goods from point of production to point of consumption)—Thirty years ago, most suppliers delivered materials to a manufacturer, who pushed products to a distributor or retailer, which then sold the products to customers. Each business in the chain maintained a large and expensive inventory of critical materials and products to protect against

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2 The economic and freight demand forecasts cited in this chapter were prepared by IHS-Global Insight, Inc. based on economic forecasts prepared in the first quarter of 2009 and on 2007 Transearch freight demand projections through 2035. The forecasts and projections were developed for Cambridge Systematics as part of a project for AASHTO to produce a series of freight transportation bottom line reports in 2008. AASHTO anticipates publishing the reports in 2011. The economic and freight demand projections incorporate the impact of the economic recessions that started in 2008.

3 IHS-Global Insight, Inc., projections

4 IHS-Global Insight, Inc. projections. GDP and trade value are not equivalent measures. GDP is a measure of the value added to goods through processing and manufacturing ,while trade value is the total sales value of imports and exports. They are compared here only to illustrate the importance of trade to the US economy and freight transportation.

stockouts. Today, most businesses are moving toward pull or on-demand supply chains, cutting costs by reducing inventory and replenishing whatever the customer consumes as soon as it is sold. This results in smaller shipment sizes (since units are consumed one by one), more individual products per shipment (to make lot sizes economical to ship), more time-sensitive shipments, and more shipments in total.

Together, these changes in consumption, production, trade, and supply chain practices will generate an additional 5.5 billion tons of freight to be moved in 2035.[5] Figure 16-5 shows the freight tonnage forecast by mode for 2005 through 2035. The forecast reflects the impact of the economic recession that started in 2008.

Measured in tons, freight demand will grow from 14.5 billion tons in 2005 to 20 billion tons in 2035—an increase of 38%. Measured in ton-miles, freight demand will grow from seven trillion ton-miles today to 9.5 trillion ton-miles in 2035—an increase of 35%.

Figures 16-6 and 16-7 show the projected shares of freight tonnage, value, and ton-miles by mode in 2005 and 2035, given current transportation policies and programs.[6] The projections indicate that trucking will remain the dominant freight service through the period reflecting its current size; its cost effectiveness for trips under 500 miles; its ability to provide reliable, door-to-door services tailored to the needs of individual shippers and receivers; and the fact that most long- and even short-distance intermodal rail and ship moves

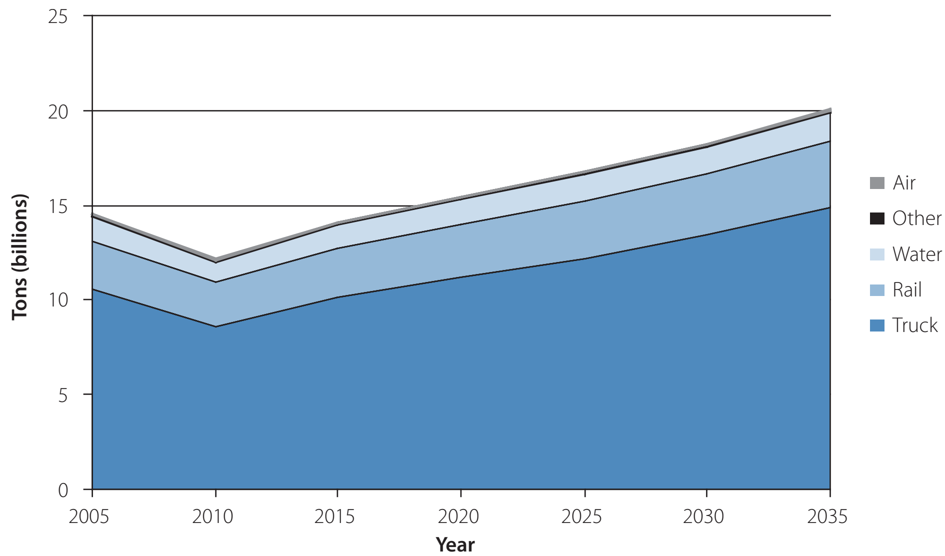
5 IHS-Global Insight, Inc., 2007 Transearch projections.

6 The freight transportation demand forecasts are driven by economic growth forecasts and estimates of the types of freight that the economy will generate. The major factor behind the economic growth rate is population growth, and the major factor behind the estimate of the types of freight that will be generated is the expectation that the US economy will continue its shift from agriculture, resource production, and heavy manufacturing toward high-technology manufacturing and services—that is, toward an economy that produces more higher-value, time-sensitive freight and less bulky, heavy, and lower-value freight.

The forecasts start with today's shares in each freight market, looking at how much freight is moved between cities and regions and by which mode—truck, rail, water, and air. If tomorrow's economy produces more freight that goes by truck today, then the truck share in the future will increase. If the economy produces less freight that moves by rail today, then the rail share in the future will decrease. The forecasts reflect the experience of recent decades; e.g., as the structure of the economy has evolved to produce relatively higher-value goods and trade has grown, businesses have favored the higher-performing transportation modes such as air freight, truck, and rail intermodal container service.

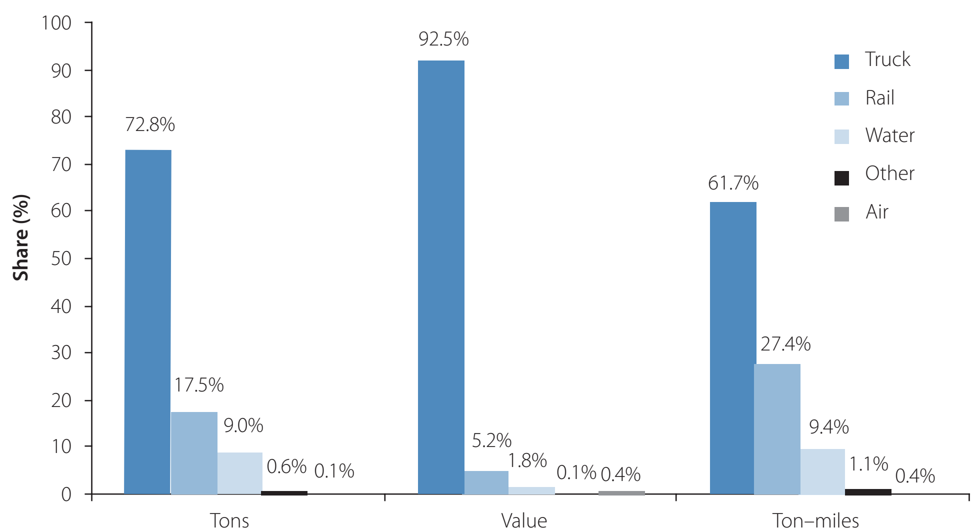
The forecast does not take into account how the freight transportation system might change as the economy grows and trade patterns change. The forecasts assume only that the transportation system will expand to accommodate the additional freight. The forecast does not predict how changes in capacity, service performance, and prices might shift commodities among modes or shift the location of business and industry. As such, the forecasts provide a policy-neutral, baseline picture of what could happen, not a definitive forecast of what will happen. The forecast provides a starting point, but a number of factors will likely change the projections of both total demand and modal shares: slower economic growth, which could result in less demand; higher energy costs, which could result a limited shift of freight from air and truck to rail and water; in-sourcing (purchasing materials and goods in the United States or North America instead of from Asia or other global trade partners), which could reduce international freight flows but increase domestic freight flows; market concentration, which could produce economies of scale favoring rail, waterborne, and pipeline transportation; and investment risk, which could favor one mode over another.

Figure 16-5 Freight tonnage forecast by mode from 2005 to 2035



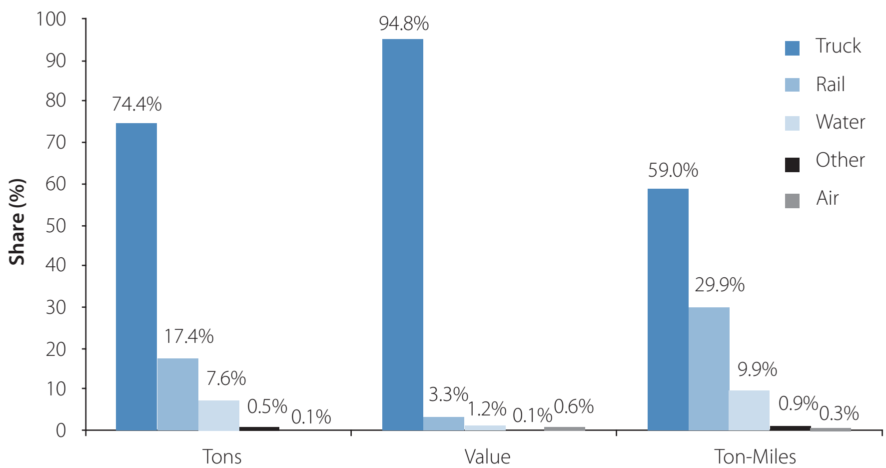
SOURCE: Projections are based on IHS-Global Insight 2007 Transearch data and economic forecasts as of April 2009, as reported in the freight transportation bottom line reports prepared by Cambridge Systematics, Inc., for the American Association of State Highway and Transportation Officials.

Figure 16-6 Freight tons, value, ton-miles by mode, 2005



SOURCE: Projections are based on IHS-Global Insight 2007 Transearch data and economic forecasts as of April 2009, as reported in the freight transportation bottom line reports prepared by Cambridge Systematics, Inc., for the American Association of State Highway and Transportation Officials.

➤ **Figure 16-7** Freight tons, value, ton-miles by mode, 2035



SOURCE: Projections are based on IHS-Global Insight 2007 Transearch data and economic forecasts as of April 2009, as reported in the freight transportation bottom line reports prepared by Cambridge Systematics, Inc., for the American Association of State Highway and Transportation Officials.

begin and end with a truck move. Today, trucking carries 72.8% of freight tonnage. By 2035 it is projected to carry 74.4%. Trucking will absorb 78.5% of the new tonnage and 51.3% of the new ton-miles.

Trucking will not be growing alone. Air freight tonnage will grow by 97% between 2005 and 2035, although total tonnage is modest. Railroads will carry 38% more than they do today. Intermodal shipments—by truck and ship, by truck and rail, or by truck and air—will increase by 2035 because of the growth of overseas trade and increasing demand for long-haul intermodal rail service as the price of truck diesel fuel increases. Trade in containerized goods is projected to expand faster than US freight overall. Intermodal shipping by rail is projected to grow at a compound annual rate close to 4% over the next 30 years.

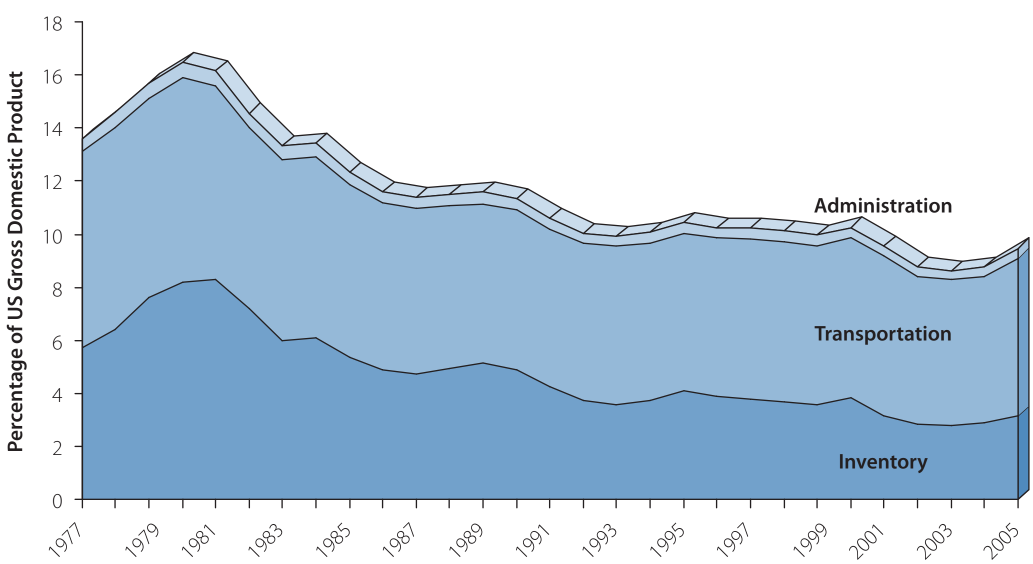
Rising energy prices and regulatory actions to reduce carbon emissions will change the total demand for freight transportation, the modal shares, and the pattern of freight movements, but the critical drivers of freight transportation demand will continue to be the overall population and economic growth rates, along with growth in global trade. The population growth rate is unlikely to change significantly by 2035, and economic growth is expected to generally track population growth over the next two decades. And while the trend toward globalization and trade may slow, it is not likely to be reversed. Short-term business cycles will shift the demand for freight transportation and affect the longer-term rate of GDP growth. However, moderate changes in the rate of GDP growth—an increase or decrease of a half of one percent—do not erase the need for freight transportation. Typically, a shift in the rate of GDP growth means that the forecast of freight demand is realized five to eight years earlier (or later) than anticipated. This is a relatively short time period compared with the time required to plan, design, finance, build, and begin operation of major highway, rail, and port infrastructure improvements.

16.5 Freight System Performance

At issue is whether the increase in demand for freight transportation will outpace the capacity of the freight transportation system, leading to increased congestion and increased freight costs. Although it is a very broad measure, the trend in total logistics cost suggests that the productivity of freight transportation is already dropping, driving up logistics costs for businesses and industries for the first time in 25 years. Total logistics cost is the cost of managing, moving, and storing goods. The major components of total logistics cost are administration (e.g., management, insurance), transportation (e.g., by truck, rail, air, and water), and inventory carrying costs. Figure 16-8 shows total logistics cost as a percentage of US GDP from 1977 through 2005. *(4)*

Logistics costs rose through the 1960s and 1970s to a high of about 16% 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. Total logistics cost

Figure 16-8 Total logistics cost, 1977–2005



SOURCE: *18th Annual State of Logistics Report.* (4)

declined through the 1980s and 1990s to a low of about 8.6% of GDP in 2003. Businesses and consumers benefited because cheaper transportation resulted in lower-cost goods and greater access to global suppliers and markets.

But total logistics cost is rising again. In 2006, total logistics cost was 9.9% of GDP. The increase reflects higher fuel costs and more congestion along transportation corridors and at major US international trade gateways. It is difficult to pinpoint the contribution of congestion to increasing logistics costs, but several analyses suggest that congestion may have accounted for a third of the increase in inventory carrying costs between 2005 and 2006.[7] Businesses and industries are concerned that increasing logistics costs will undermine future economic productivity, international competitiveness, and US economic growth.

16.6 Highway Freight Network Congestion

The highway freight system is the nation's premier freight transportation system. In 2005, trucks on highways carried 73% of all domestic freight by tonnage and 93% of freight by value, accounting for 62% of all ton-miles of freight moved (a ton of freight moved a mile counts as one ton-mile.).[8] Truck freight moves over the following three tiers of roadways:

- The Dwight D. Eisenhower System of Interstate and Defense Highways (Interstate Highway System), which is the backbone of the nation's truck freight system, connecting major cities and international gateways and carrying about one-half of all truck miles of travel;
- The National Highway System, which includes the Interstate Highway System and other major US and state freight highways; and
- State and local roadways, which provide truck access for local pickup and delivery of freight to businesses, farms, ports, airports, warehouses, retail stores, and homes.

Figure 16-9 compares the extent and coverage of the three roadway systems. Figure 16-10 maps the density of large truck traffic on the Interstate Highway System and other National Highway System roads in 2005. Density is calculated as the annual number of large trucks (i.e., five-axle tractor semitrailers) by highway segment. The map does not account for smaller trucks such as local delivery trucks, construction trucks, and service vans. The wider the blue band, the higher the number of trucks using that roadway.

7 Estimate prepared for Cambridge Systematics by Boston Strategies International, Inc., for the AASHTO freight transportation bottom line report series.

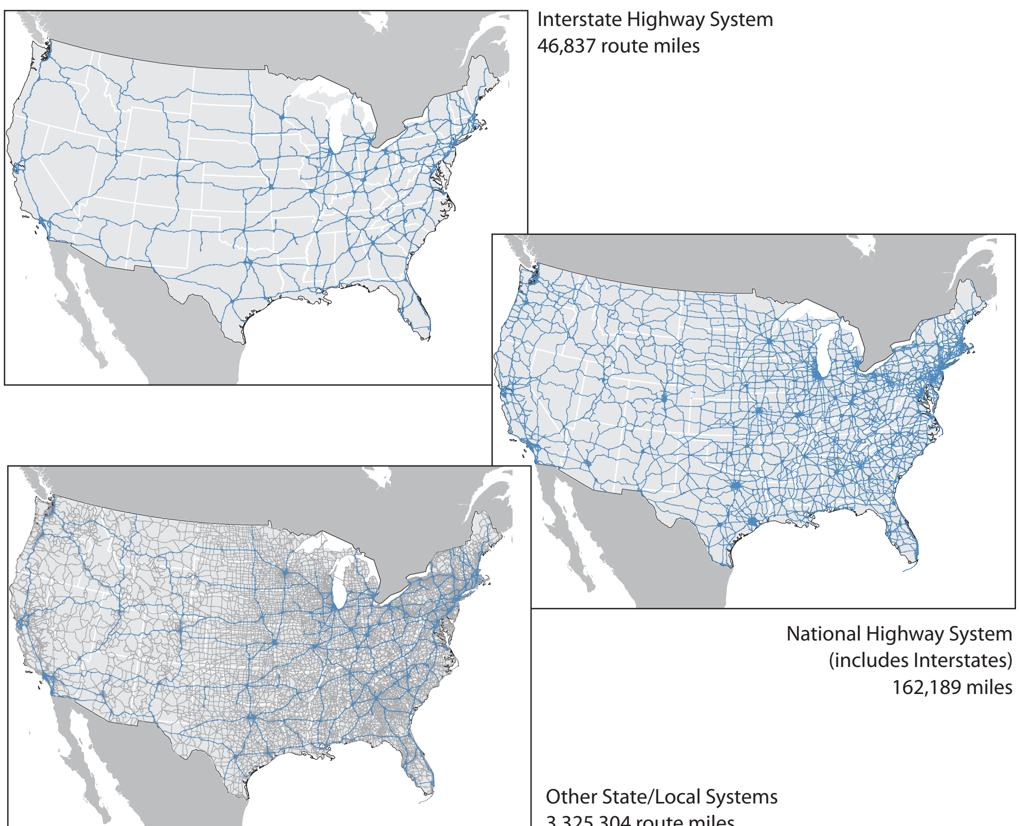
8 IHS-Global Insight, Inc., 2007 Transearch data.

The projected growth in freight demand and the increase in tonnage and ton-miles carried by trucks could more than double truck traffic on the major corridors. Figure 16-11 shows the projected change, or growth, in truck volumes in 2035 compared with 2005.

The number of automobile and local truck trips will also grow with population and the economy. The result will be more traffic and more traffic congestion nationally. Figure 16-12 shows the levels of congestion on major roadways in 2007. *(5)* Blue indicates highway sections where peak-period traffic exceeds the roadway capacity. Figure 16-13 shows the anticipated levels of congestion in 2040. The map shows more intensive traffic and congestion in major metropolitan areas, more traffic and congestion in medium and smaller cities, spreading congestion along major intercity routes, and a concentration of traffic and congestion at major international marine and land gateways.

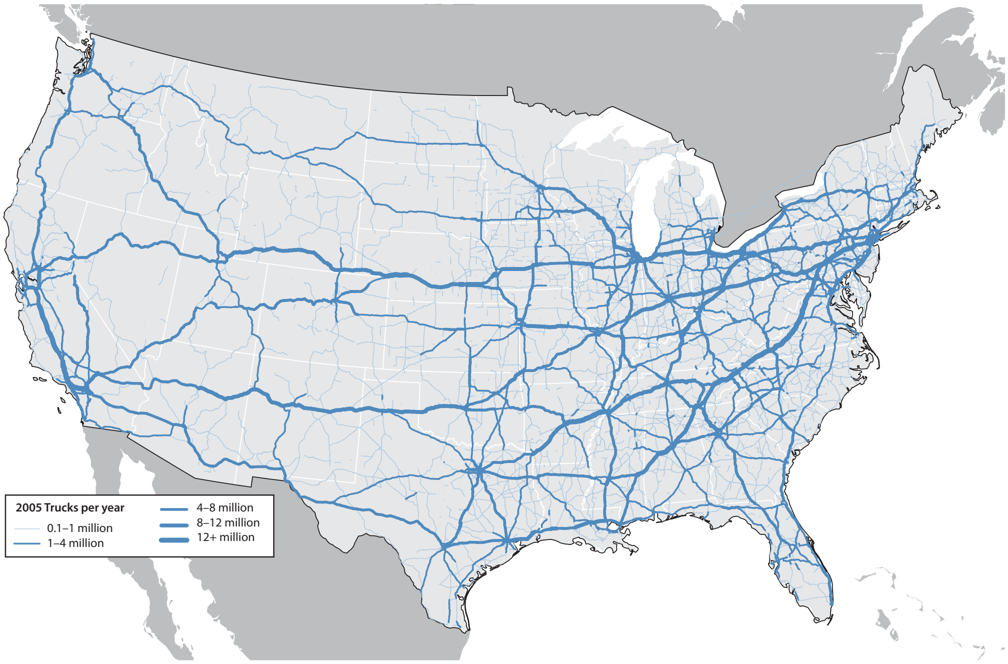
Much of the congestion will occur at bottlenecks on the highway system. Bottlenecks are specific physical locations on highways that routinely expe-

➤ **Figure 16-9** Main freight routes of the Interstate Highway System, National Highway System, and state and local road system



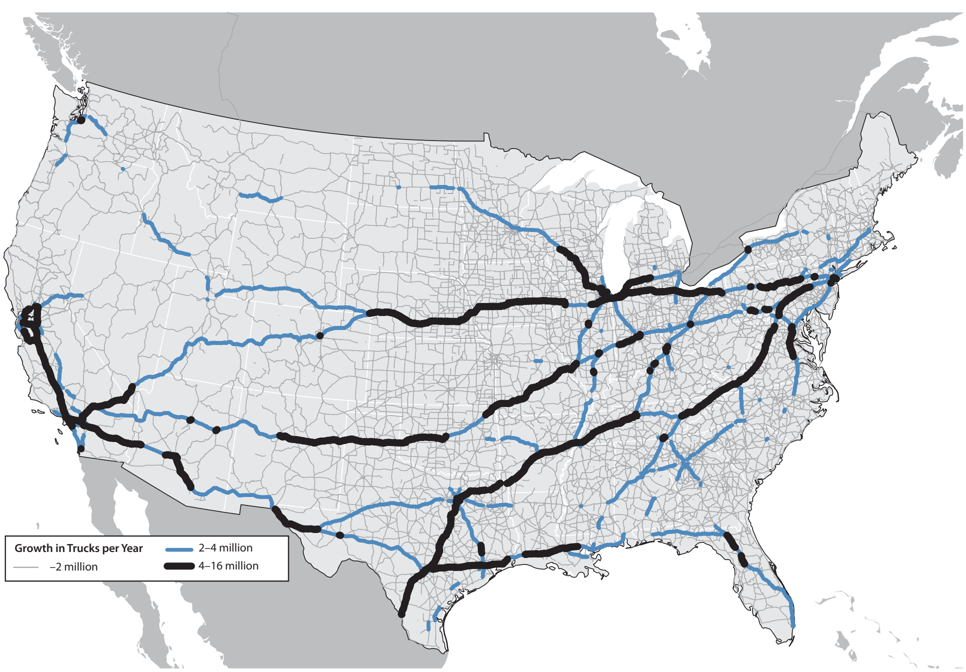
SOURCE: US Bureau of Transportation Statistics, *National Transportation Atlas Database.* 2bts.rita.dot.gov/publications/national_transportation_atlas_database/

Figure 16-10 Truck traffic on US highways, 2005



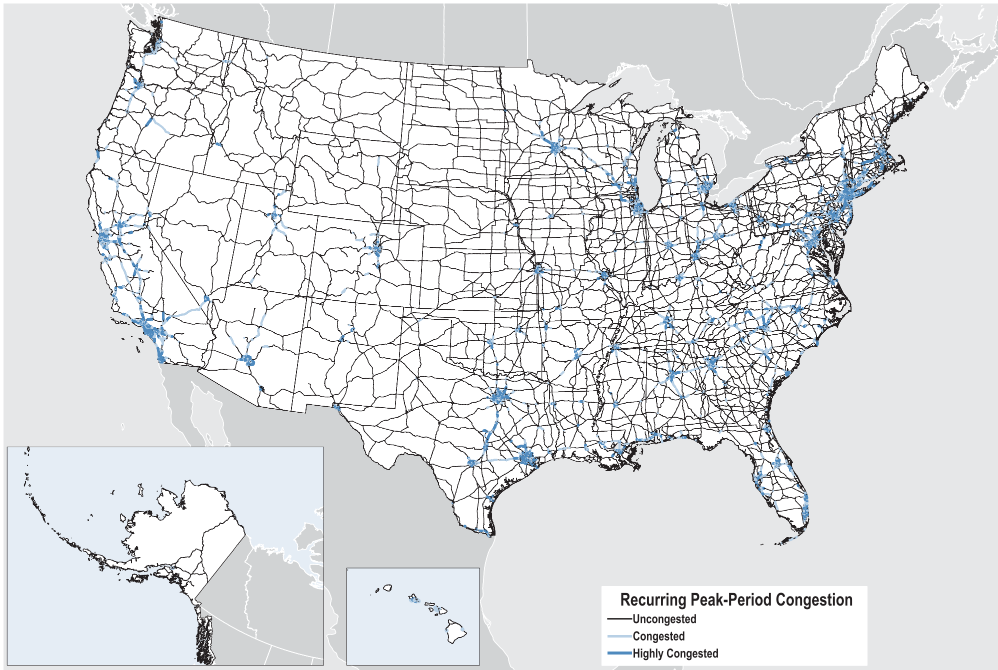
SOURCE: IHS-Global Insight, Inc. 2007 Transearch data and economic forecasts.

Figure 16-11 Change in truck volumes from 2005 to 2035



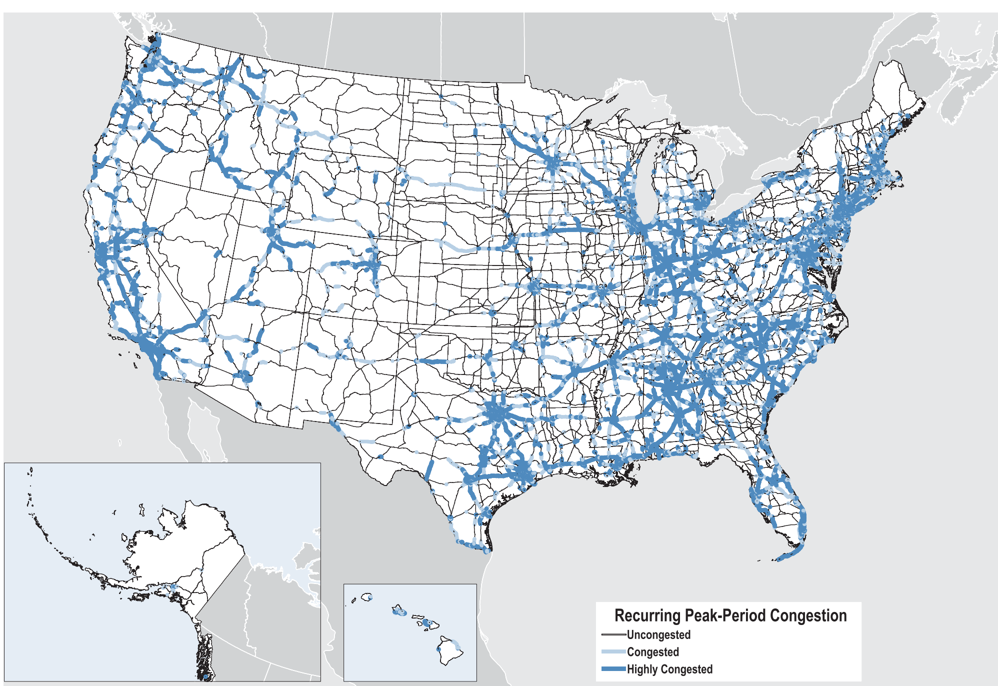
SOURCE: IHS-Global Insight, Inc. 2007 Transearch data and economic forecasts.

Figure 16-12 Congested highways, 2007



SOURCE: Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework (FAF3). Maps and related data available at www.ops.fhwa.dot.gov/freight/freight_analysis/index.htm.

Figure 16-13 Potentially congested highways, 2040



SOURCE: Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework (FAF3). Maps and related data available at www.ops.fhwa.dot.gov/freight/freight_analysis/index.htm.

rience recurring congestion and traffic backups because traffic volumes exceed highway capacity. A recent study for FHWA examined highway bottlenecks and estimated the annual truck-hours of delay associated with each type of bottleneck. *(6)* The study identified highway bottlenecks that cause 226 million hours of delay annually to freight trucks. At a delay cost of $32.15 per truck hour, the conservative value used by the FHWA's Highway Economic Requirements System model for estimating national highway costs and benefits, the direct cost to truckers of these bottlenecks was estimated at $7.3 billion per year.[9]

Bottlenecks at urban interstate highway interchanges accounted for most of the delay reported in the FHWA study—about 151 million hours of delay. Figure 16-14 shows the location of the major highway interchange bottlenecks for freight trucks in 2006. The bottleneck locations are indicated by a solid dot. The size of the circle accompanying each dot indicates the annual truck-hours of delay associated with the bottleneck.

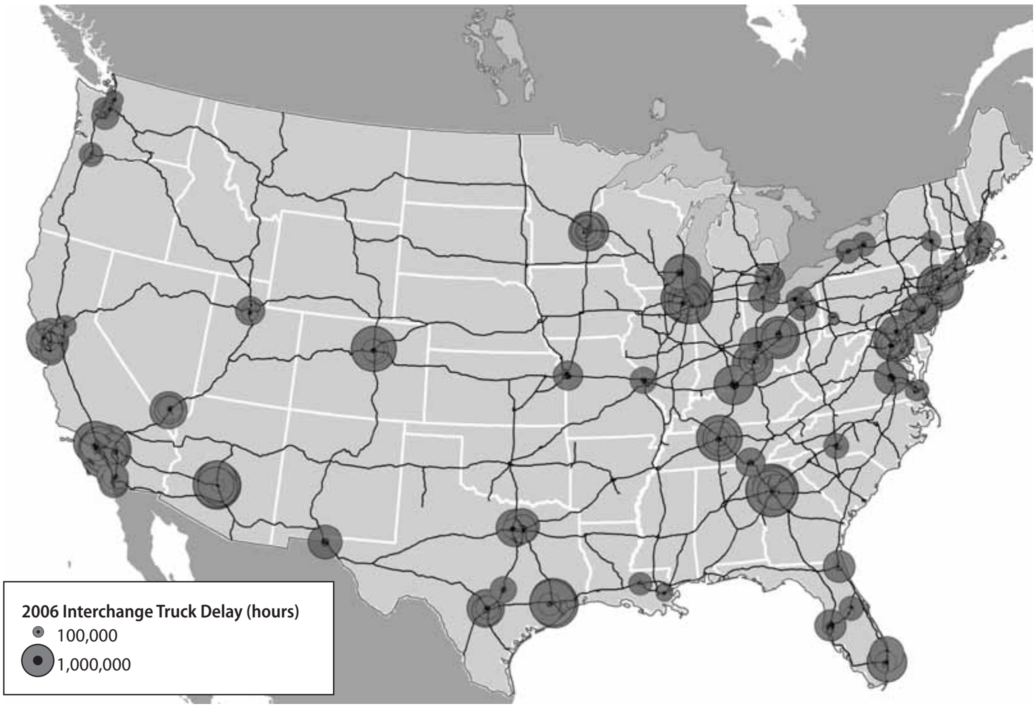
The projected congestion is expected to hold down trucking productivity and drive up logistics costs. Trucking productivity—measured as cost per mile or as labor hours required to deliver a shipment—has lagged other freight transportation modes in recent decades. Figure 16-15 compares the labor productivity of long-distance freight trucking services with line-haul railroads (i.e., Class I railroads). *(7)* Between 1987 and 2006, labor productivity in the railroad industry increased 142%, compared with 31% for the trucking industry. The figure shows productivity trends for these industries and for comparison shows the productivity trends for air transport and the US Postal Service.

Transportation engineers and planners are developing a broad range of strategies, arrayed in Figure 16-16, to deal with highway and metropolitan roadway congestion. These fall into three general categories: adding more capacity; operating existing capacity more efficiently; and managing demand. Within these general categories, several specific strategies have direct benefits for freight truck movement:

- Redesigning bottlenecks. Since the worst highway bottlenecks tend to be freeway-to-freeway interchanges, engineers are exploring advanced design treatments that spread out turning movements and remove traffic volumes from key merge areas, often by using multilevel highway structures that minimize the footprint of the improvement on the surrounding landscape. Widening adjacent arterial roads, providing street connectivity, providing grade separations at congested intersections, and adding high-occupancy vehicle (HOV) lanes can further reduce congestion by diffusing automobile traffic away from critical bottlenecks.

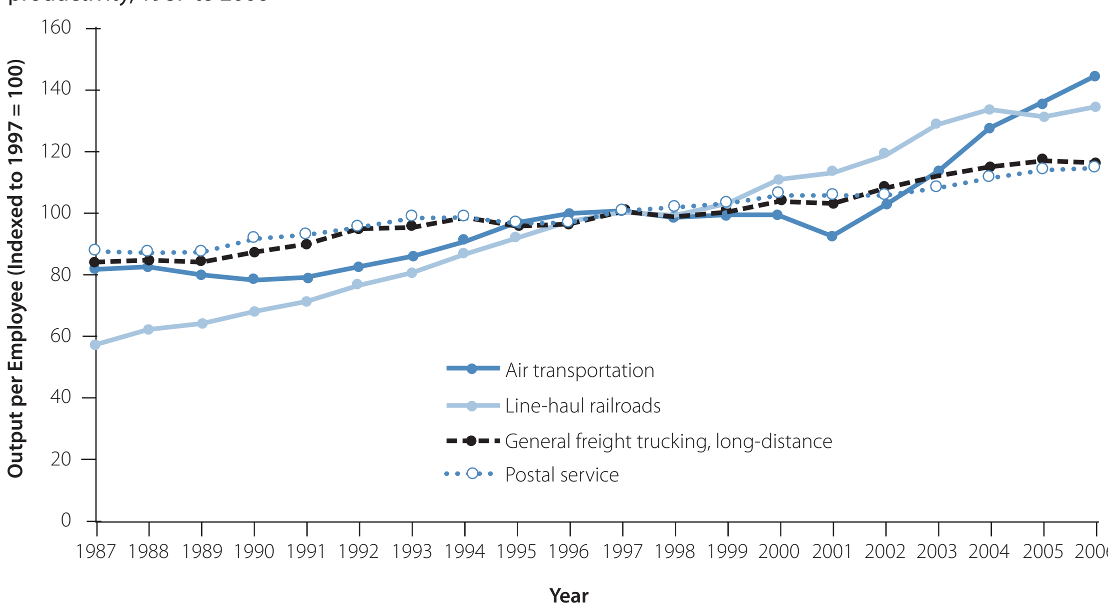
9 The FHWA Highway Economic Requirements System model uses a value of truck time of $32.15 per hour. Other researchers have suggested higher rates, typically between $60 and $70 per hour.

Figure 16-14 Major highway bottlenecks for freight-trucks



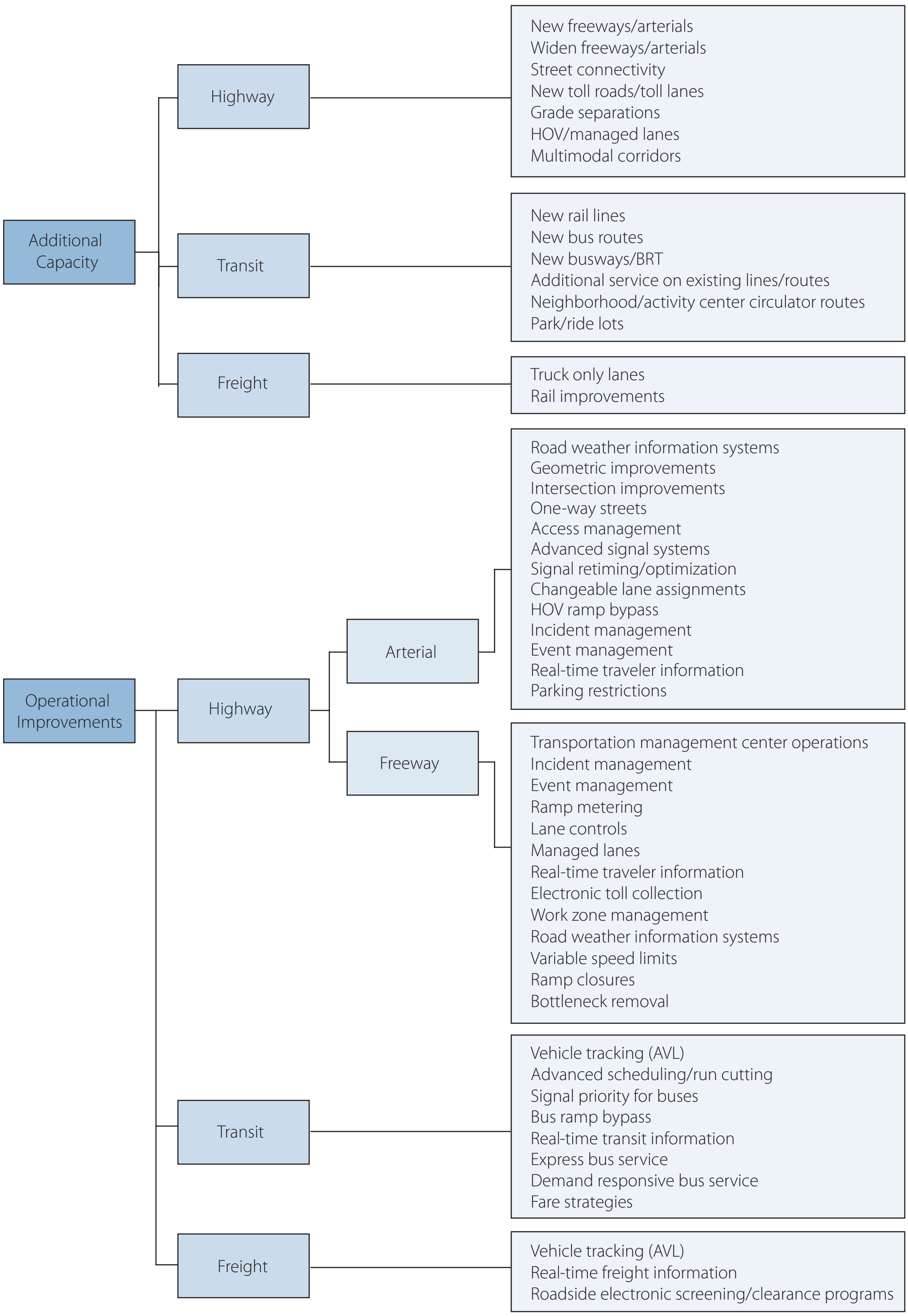
SOURCE: *Estimated Cost of Freight Involved in Highway Bottlenecks.* (*6*)

Figure 16-15 Trucking productivity trend compared with selected transportation industry productivity, 1987 to 2006



SOURCE: Table 3-24b: Labor Productivity Indices for Selected Transportation Industries (North American Industry Classification System Basis). (*7*)

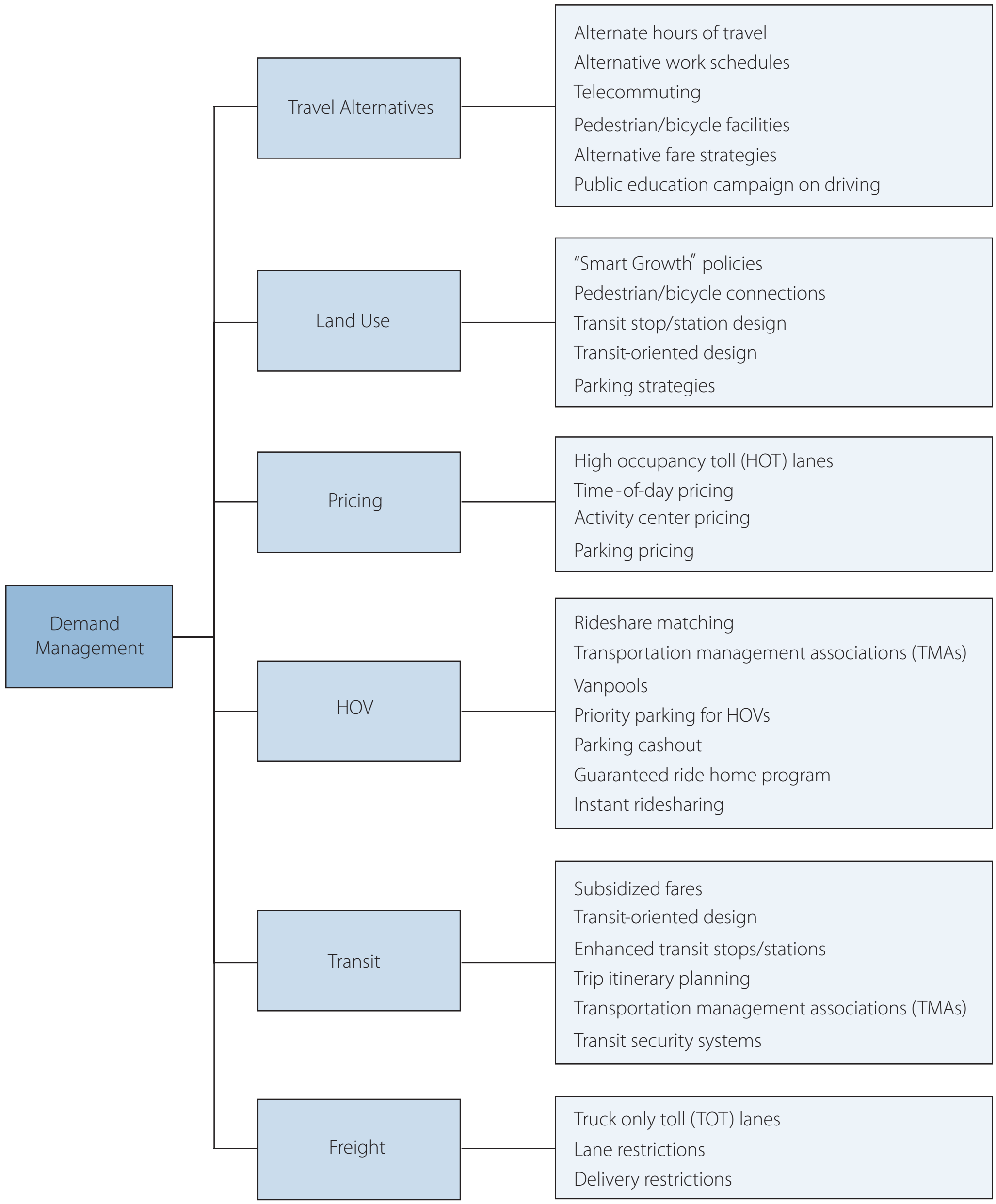
Figure 16-16 Strategies for reducing highway congestion



SOURCE: Cambridge Systematics, Inc.

(continued)

Figure 16-16, *continued*



- Managing traffic flows. Transportation system management and operations includes the application of advanced technologies using real-time information about highway conditions to implement control strategies. Collectively referred to as intelligent transportation systems, real-time control of highway operations through a transportation management center includes metering flow onto freeways, dynamically retiming traffic signals, managing traffic flow during incidents, and providing travelers with information about travel conditions, alternative routes, and other modes. Although typically not targeted specifically to freight trucks, these strategies improve travel time reliability, a critical consideration in freight transportation operations.

- Pricing road use. Under the rubrics of tolling, value pricing, congestion pricing, cordon pricing, and variable demand pricing, these strategies attempt to manage congestion by creating a market for highway space and time. Higher prices are set for use of roadways during the most congested times and lower prices for use of roadways during uncongested times. A portion of truck freight trips carry cargo of sufficiently high value and time sensitivity to warrant paying for access and reliable trip times.
- Expanding transit service. Adding capacity to bus, light rail, subway, and commuter rail systems to divert trips from automobiles frees roadway space and time for truck movement.

Transportation engineers and planners are also exploring advanced operational technologies that offer the promise of further congestion mitigation. These include the following:

- Speed harmonization. By slowing all vehicles uniformly as congestion builds on a freeway, optimum flow can be maintained. The intent is to avoid the rapid stop-and-go of vehicles, which causes "shock waves" to appear in the traffic stream.
- Dynamic lane control. Lane control systems direct motorists to specific lanes in advance of bottlenecks so that vehicle merging is controlled and spread out over a longer distance. This helps maintain traffic speeds and reduces the risk of crashes that account for much of the congestion on urban interstate highways.
- Active safety controls. Examples include intersection collision avoidance, violation warning, turn conflict warning, road departure warning, and vehicle-to-vehicle collision and avoidance/mitigation systems. These controls depend on deployment of real-time communications among vehicles and between vehicle and roadside traffic-control devices.
- Real-time flow data. Many freight trucks are equipped with satellite-based communication and GPS systems. As these technologies migrate to automobiles and small trucks and as short-range vehicle-to-vehicle communication technologies are introduced, they will create a web of vehicle probes—instrumented cars and trucks—capable of sensing and relaying data about highway and roadway conditions that will improve the collection and distribution of information about road weather conditions, construction zone speeds, traffic flow speeds, pavement conditions, status of loading docks, etc.

16.7 National Rail Freight Network/Terminals

As the cost of highway freight bottlenecks and congestion has increased, policy makers at all levels of government have started looking to the railroads to carry more freight to relieve highway congestion. Shippers, too, have started looking to railroads to carry more long-distance shipments, especially as the costs of truck fuel and driver labor have increased. *(8)*

Demand for rail freight transportation is pressing the capacity of the nation's rail system today. (See Chapter 6 for a description of the US rail system.[10]) The ton-miles of rail freight 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. In the 1980s, railroads had substantial surplus capacity—the result of a long-term shift of freight from rail to truck that started in the 1930s and accelerated after World War II with the improvements in highways and truck design. The loss of market share left railroads with many miles of underutilized track. This excess capacity enabled the railroads to absorb traffic growth in the 1990s by making relatively modest additional capital commitments to expand infrastructure where new demand for freight transportation matched existing rail corridors. However, this surplus capacity has now been largely absorbed by two decades of growth and by major increases in rail traffic volumes during the past few years.[11]

In 2007, the congressionally mandated National Surface Transportation Policy and Revenue Study Commission asked the Association of American Railroads (AAR) to estimate the capacity and investment needed to keep up with the US Department of Transportation's projected economic growth and the accompanying demand for freight transportation services through 2035. The resulting *National Rail Freight Infrastructure Capacity and Investment Study* found that the railroads must add capacity to handle at least 60% more tonnage and 73% more ton-miles by 2035, based on the US Department of Transportation freight demand projections at that

10 Class I railroads are defined as having 2008 revenues of $401.4 million or more. There are seven Class I railroads operating in the United States. These railroads provide long-haul rail freight services throughout the United States with connections to Canadian and Mexican railroads for international traffic. The Class I railroads form the backbone of the US rail system, accounting for 68% of the system mileage, 89% of the employees, and 93% of the freight revenue. Regional railroads are railroads that operate at least 350 miles and have annual revenues greater than $40 million, but less than the Class I threshold. Local railroads are all other freight railroads that are not Class I or regional railroads. They are defined as railroads operating under 350 miles of road and earning less than $40 million annually. They include local line-haul railroads and switching and terminal operations railroads.

11 Much of the new demand for rail freight transportation has been in intermodal and coal unit-train transport. Where demand matched existing rail lines, the railroads have invested to upgrade and expand the lines. Where there has been no demand for existing rail lines, the Class I railroads have sold off the lines to short line and regional railroads or abandoned the lines altogether. Today's rail system has about half the number of rail-miles that were in operation in the 1920s at the peak of the rail era.

time.[12] Figure 16-17 shows the projected growth in trains between 2005 and 2035. 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 blue 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 16-18 compares 2035 volumes in trains per day with current corridor capacity, assuming no expansion of capacity to meet future demand. The volume-to-capacity ratios are expressed as level of service (LOS) grades for each primary rail corridor. For legibility, rail corridors operating at LOS A, B, and C (where future demand remains below existing practical capacity) are mapped in a thin grey line. Corridors operating at LOS D (where future demand is projected to be near existing practical capacity) are mapped in a thick black line, and corridors operating at LOS E (where future demand is projected to be equal to existing practical capacity) are mapped in light blue. Rail corridors operating at LOS F (a condition where demand is projected to be above existing available capacity) are mapped in dark blue.

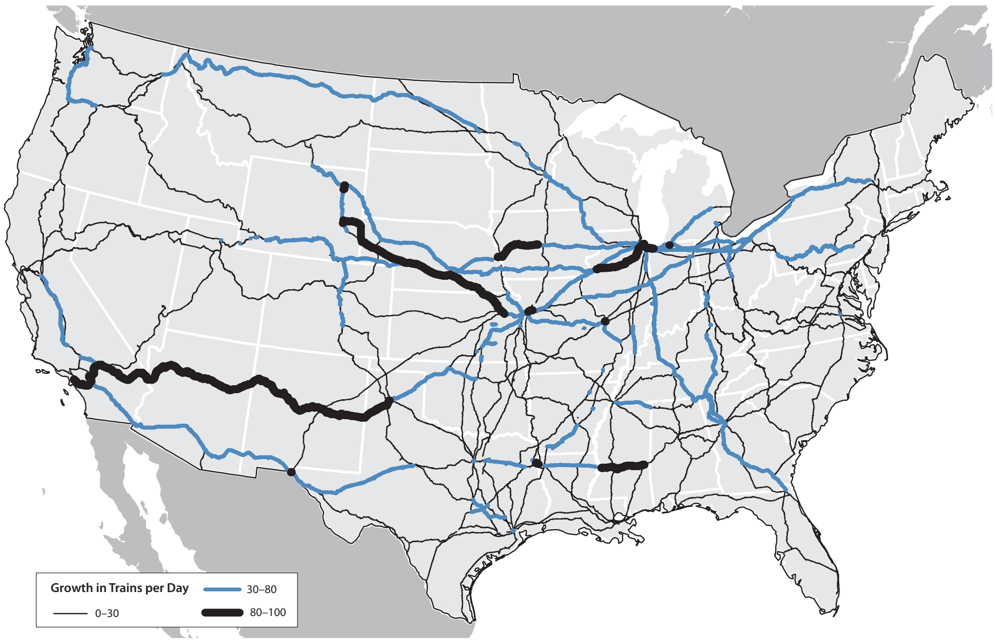
The study found that many of the key national rail corridors supporting domestic and international trade will be facing severe capacity shortfalls in coming years if capacity is not expanded systemwide and in step with economic growth and demand. The study estimated that an investment of $148 billion (in 2007 dollars) for rail infrastructure expansion over the 28 years between 2007 and 2035 is required to keep pace with economic growth, meet the US Department of Transportation's freight demand forecast, and avoid these capacity shortfalls. Of this amount, the Class I freight railroads' share is projected to be $135 billion, and the short line and regional freight railroads' share is projected to be $13 billion. *(8)*

At issue is whether the railroads can raise the necessary capital and expand fast enough to meet the demand for rail service in the future. The performance of the Class I railroads has improved significantly since 1981, the first year after the rail industry was deregulated under the Staggers Act. Figure 16-19 shows the trends in productivity, volume, revenue, and price.

Overall, the rail industry today is stable, productive, and competitive with

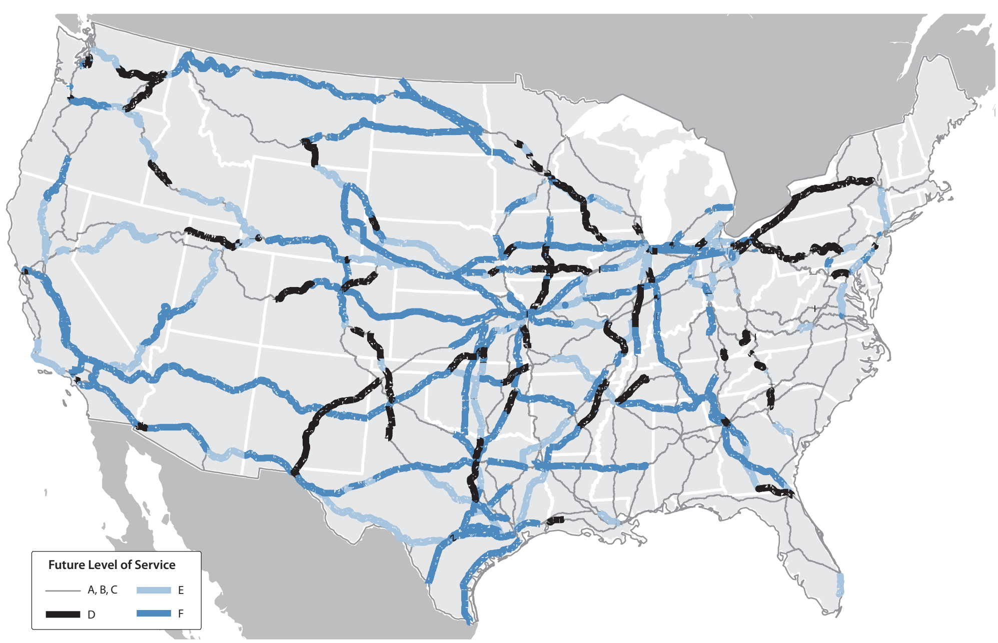
12 The US Department of Transportation's Freight Analysis Framework Version 2.2 freight demand forecast, which was used for the *National Rail Freight Infrastructure Capacity and Investment Study,* projected that the demand for rail freight transportation—measured in tonnage—would increase 88% by 2035. The IHS-Global Insight 2004 Transearch freight demand forecast, which was used for the initial drafts of the AASHTO freight transportation bottom line reports, projected that the demand for rail freight transportation—also measured in tonnage—could grow by 60% by 2035. The percentage changes were different because the forecasts used different base years; however, the tonnage projections for 2035 were similar. The current IHS-Global Insight 2007 Transearch freight demand forecast projects that demand for rail freight transportation—again, measured in tonnage—could grow by 38% by 2035. The lower growth rate reflects the severe impact of the current recession. Although demand is growing more slowly than projected in the AAR study, railroad investment in capacity expansion is also slowing apace. Even with lower total demand in 2035, the risk of a capacity shortfall may remain the same.

Figure 16-17 Change in trains per day from 2005 to 2035 by primary rail corridor



SOURCE: *National Rail Freight Infrastructure Capacity and Investment Study.* (8)

Figure 16-18 Future corridor volumes compared with current corridor capacity, 2035 without Improvements



SOURCE: *National Rail Freight Infrastructure Capacity and Investment Study.* (8)

enough business and profit to operate, but the industry is still not attracting capital fast enough to replenish its infrastructure quickly nor to keep pace with demand and public expectations. This is occurring because railroading is an extraordinarily capital-intensive industry, and railroads, investors, and lenders tend to be very cautious about overinvesting in infrastructure.

The rail industry spends three to five times as much on infrastructure as other major industries. The railroads must continuously replenish tracks, bridges, signals, locomotives, freight cars, maintenance equipment, and information technology. Because the system is operated as a tightly integrated network, almost all rail corridors must be maintained to sustain the carrying capacity of the entire network. Failure to maintain a section of track can idle miles of track before and after that section, delaying the movement of rail traffic hundreds of miles away.

From 1996 through 2005, the Class I railroads reinvested an average of 17% of their revenue in capital improvements, compared with an average of 3% for all other US industries. In 2006, the Class I railroads spent $10.6 billion maintaining and improving their infrastructure and another $8.7 billion on replacing equipment, for a total of almost $20 billion out of total revenues of $52.2 billion.[13] This rate of investment was maintained into early 2008, but has been dropping quickly as rail traffic declines with the economy.

Capital investments are made selectively, with most capacity-expansion investments targeted carefully at specific lanes and commodities. The financial pressure to be conservative in investing in capital improvements is reinforced by a railroad management culture that remembers clearly the bankruptcies of the pre–Staggers Act industry. Moreover, because the freight railroads are closely regulated, it is very difficult to shut down or abandon a rail line during economic downturns. The result is that during times of low demand, railroads cannot shed costs quickly, and during times of high demand, they cannot add capacity quickly, creating mismatches between demand and rail supply.

But increasing demand is catching up with the restructured rail system, resulting in rail congestion and deteriorating service levels in many rail corridors and at interchange locations. In response, the Class I railroads are beginning to add track, lengthen sidings, improve signaling, and upgrade track to support more traffic and heavier loads. In recent years, railroad investment in expansion (not replacement) has jumped from about $1 billion annually to nearly $2 billion annually. But the financial pressures to invest in expansion and remain profitable also are forcing the railroads to concentrate on more profitable wholesale rail services, such as longer-distance, international intermodal traffic and domestic coal traffic. They are slowly pricing out the more costly and less profitable shorter-distance industrial carload traffic that was once the core of the railroads' common carrier business.

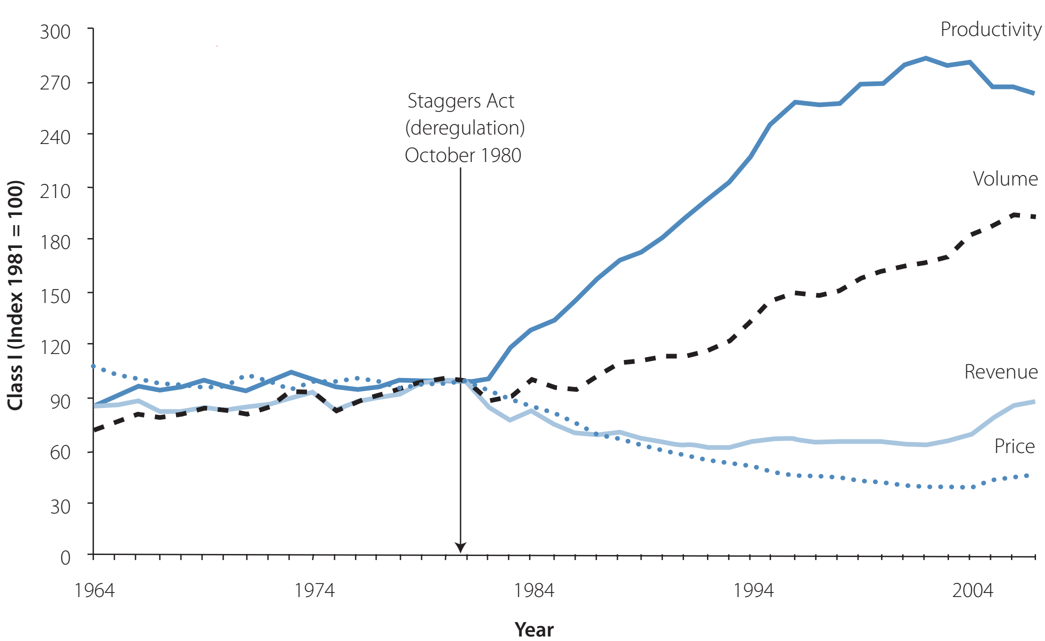
13 AAR data as reported in the *National Rail Freight Infrastructure Capacity and Investment Study.* (*8*)

The AAR study estimates that the Class I railroads could generate approximately $96 billion of the $135 billion share of expansion costs 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. The current expectation is that the railroads will generate more revenue as demand increases, but may not be able to invest enough to keep pace with economic growth. Instead, they will continue to shed traffic to trucks, increasing congestion on the highways.

Strategies for expanding capacity and reducing congestion focus on infrastructure and operations, including the following:

- Expand mainline capacity and develop new rail corridors. Railroads are investing heavily—using their own revenues and monies borrowed in the capital market—to expand mainline capacity. In most cases, this involves replacing or adding track within existing rights-of-way, which nevertheless demands billions of dollars. The industry has begun to entertain proposals that establish rail corridors where none now exist. There are discussions about possible new routes perhaps south of Chicago that would allow some transcontinental traffic to bypass the congested Chicago rail hub. The industry generally can be expected to expand mainline routes, but continue to

Figure 16-19 US railroad performance, 1964 to 2007



SOURCE: *National Rail Freight Infrastructure Capacity and Investment Study.* (8)

contract or sell off branch lines. The need to expand freight rail capacity will also be affected by the rate at which commuter rail and especially intercity passenger and high-speed passenger rail services are introduced. As yet, there is no comprehensive assessment of the impact of expanding both passenger rail and freight rail demand and capacity.

- Upgrade signal and control systems to increase throughput on mainline tracks. Railroads are moving steadily toward elimination of mechanical signals in favor of GPS-based control systems on the main freight corridors. Remote control devices are commonly used in rail yards today to reposition trains without the need for an engineer on board. The next generation of investment in telecommunications and control infrastructure will be targeted at automatic train control systems, at least in the most heavily trafficked and profitable mainline corridors. These systems will allow trains to operate safely at reduced headways, thus creating additional network capacity. The railroads would like to move towards one-person crews on trains, with a futurist vision of automated trains controlled and operated from a central location; however, the last major attempt to introduce one-person crews—by the Wisconsin Central in the late 1990s—was stymied by labor and state opposition. The transfer of military technology and experience with pilotless drones is expected to accelerate proposals for automated operations, pushing at least portions of the rail system in the direction of large-scale conveyor systems that provide relatively high-speed and reliable freight transfer between major intermodal logistics centers at lower transportation costs.

- Use pricing and yield management to match demand to supply. Much like the current proposals to use road pricing tolls to better match highway supply and demand, railroads have been adjusting prices to better match rail capacity and demand. By adjusting prices to discourage low-margin traffic, rail carriers can free capacity for markets with the best return on invested capital—which in turn attracts capital for expansion. Some industry analysts anticipate that railroads will follow the business model of the steamship lines and telecommunications industries by selling wholesale capacity on trains by traffic lane, time, and reliability of delivery. This allows for yield management pricing, similar to that used for airline seats and hotel rooms. Some also anticipate the emergence of a commodity futures markets for train and shipment slots, although earlier experiments with railroad futures contracts never took hold.

- Operate longer and heavier trains, focusing on scheduled unit train operations. Consistent with the shift toward wholesale rail operations, railroads are introducing more and longer single-purpose unit trains instead of mixed consists. Dedicated intermodal double-stack trains a mile and a half long have become a common feature of contemporary North American railroading. In the same way that bulk unit trains of coal and grain have been run for years, intermodal railcars are assembled and loaded at an origin terminal, then hauled directly to a destination terminal for unloading. Few if any stops are made en route to add or remove (set out) cars. This streamlined form of operation protects service reliability while reducing cost and travel time. To increase the appeal of these products to shippers demanding frequent and reliable service, and to spur the utilization of their assets, rail carriers are moving aggressively toward scheduled operations. Running trains on a fixed schedule runs the risk of sending some trains off partially loaded and failing to maximize revenues, but scheduled services are generally productive because the entire operation functions predictably, with higher rail fleet velocity (throughput) and greater delivery reliability for shippers and receivers. Underpinning these operating strategies are the assumptions that the industry will continue to see fast and sustained growth of intermodal freight, and that more and more rail shipments will be tendered in containerized form.

- Encourage short line and third-party consolidation of rail traffic. The corollary to the railroads' shift toward intermodal freight and hook-and-haul services is the shift away from the traditional carload business, where small lots of cars are collected from widely distributed shippers and delivered to many equally dispersed receivers. The cost of gathering and delivering carload shipments today is borne to a substantial degree by short line rail carriers. Short lines generate only 9% of railroad revenue, yet they originated or terminated about half of the rail industry's nonintermodal shipments in 2005, contributing more than 11 million carloads. Where they do have mainline capacity to fill, Class I railroads have encouraged third parties to consolidate carload shipments and deliver ready-to-go blocks of railcars that can be delivered nonstop to a single destination.

- Merge railroads to form two North American Class I railroads. It is probable that railroads will renew their exploration of mergers in the coming decades. The need to find continuing economies of scale and connectivity for wholesale railroad operations could lead to further consolidation of Class I networks. The current speculation is that discussions may lead eventually to the formation of two major railroad companies operating throughout the continent. Some combination of the two big US carriers east of the Mississippi would merge end-to-end with the two in the west, and the two Canadian and two main Mexican systems (along with their US properties) would join to form a pair of North American Class I railroads. The trigger for such a merger could come from within the US Class I railroads or from outside the United States. While consolidation is not imminent, and the benefits from elimination of duplicate assets are not likely to be significant, service upgrades from the reduction of traffic interchange (that is, the need to pass railcars from one railroad to another at boundaries of their operating areas) could have a strong positive effect, especially in intermediate length markets. In addition, large, unified networks create significant opportunities for improvement in equipment utilization and operating density, and they intensify the competitive influence of fixed facilities, such as major intermodal terminals.

16.8 Port Gateways

Ports, rail terminals, and distribution centers are the interchange points for the freight highway, rail, and waterborne freight networks. The most critical element is ports, which link the waterborne freight system to the highway and rail systems. *(9)* The waterborne freight system has three tiers of ports and waterways, as follows:

- The "blue water" (seaport) system handles 96% of international waterborne tonnage and 65% of total marine transportation system (MTS) tonnage. It carries virtually all of the nation's international trade in high-value containerized goods, as well as much of the nation's imported petroleum and exported food and manufactured products.
- The Great Lakes/St. Lawrence system handles 11% of MTS domestic tonnage and 7% of MTS total tonnage. It handles over one-third of the nation's domestic waterborne trade in ores and aggregates. Other important commodities include coal and primary manufactured goods.
- The inland system includes shallow-draft intracoastal waterways, rivers, canals, and locks. The system handles 68% of MTS domestic tonnage and 28% of MTS total tonnage. It carries food and farm products, primary manufactured goods, coal, and chemicals.

Figure 16-20 maps the location of the top US blue-water container ports, which have seen rapid growth as the primary gateways for international import and export traffic. The size of the circles indicates the number of containers handled by the ports. The number of containers is measured in 20-foot equivalent units (TEUs). The standard, international, oceangoing container is 40-feet long and is counted as two TEUs. The volumes for the closely adjacent ports of Los Angeles and Long Beach have been combined, as have the volumes for the closely adjacent ports of Seattle and Tacoma.

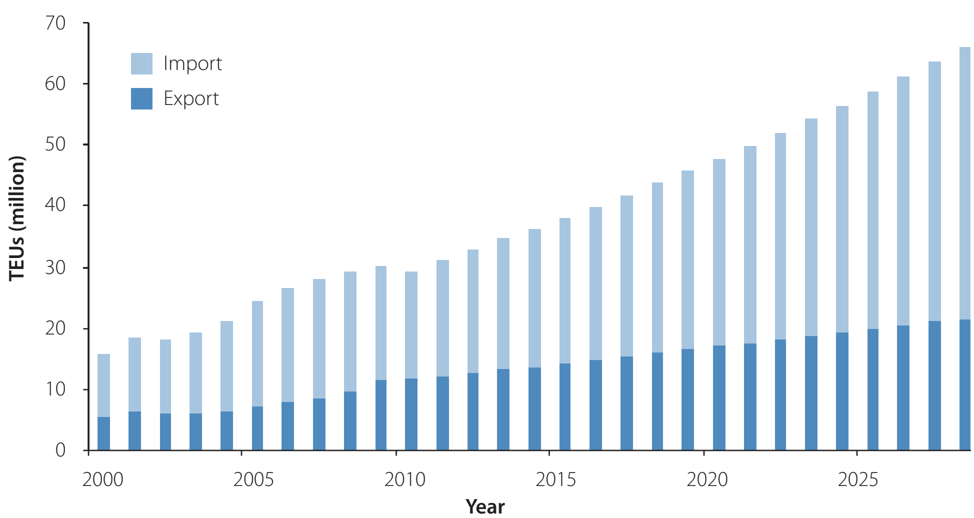
The volume of traffic moving through these ports is projected to grow steadily, as shown in Figure 16-21.

While some ports have limited physical space to handle and store containers and bulk cargoes, the dominant problem facing the US ports is access to and from the ports—by water, by rail, and by highway. On the water side, access is constrained by channel depth, which limits the size of the ships that call at

Figure 16-20 Top US container ports by TEUs in 2005

SOURCE: Waterborne Freight Transportation Bottom Line Report. (*9*)

Figure 16-21 Forecast Growth in US container trade in millions of TEUs, 2000-2025



SOURCE: IHS-Global Insight, Inc., World Trade Service data.

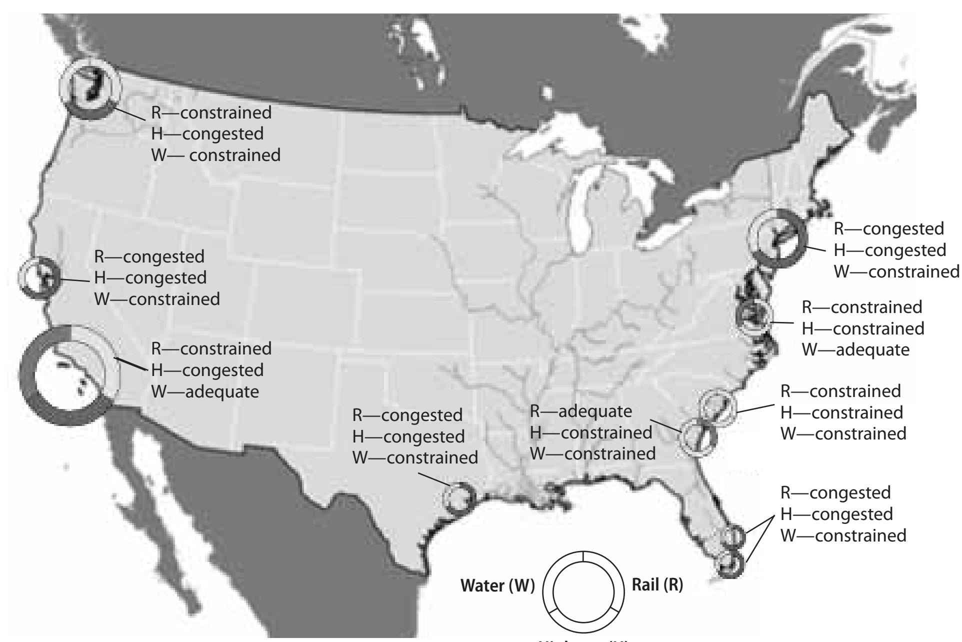
the port. The largest of the modern mega-containerships and tankers can be accommodated only at a limited number of US ports, and most of those ports must routinely dredge and deepen their harbor channels and pier areas to maintain access. On the landside, rail and highway access varies from adequate to congested. Some ports have on-dock rail access and direct highway connections to the Interstate Highway System, but most must haul containers and other freight by truck from the docks over local roads to the nearest railroad loading facility or distribution center.

Figure 16-22 shows the approximate level of congestion or constraint on water, rail, and highway access to the top US container ports. The rings show the location of the ports. Each ring is divided into three segments, representing water, rail, and highway access. The assessments are based on the access conditions reported by the ports, shippers, carriers, the press, and state and local transportation agencies.

The quality of access to and from ports is important because it affects the cost of moving containers and bulk freight, determines the market area that can be served cost effectively from the port, and impacts the communities surrounding the ports. The major ports have very large catchment areas, often serving markets across the country.

There are no comprehensive assessments that compare projected freight demand with current and planned capacities of US ports, as there are for the highway and rail systems. However, many individual ports routinely estimate future market demand and investment needs. Most report that if the market grows, they will be able to generate sufficient investment to meet demand. However, most port business forecasts focus only on capacity and operations within their gates. The growing capacity challenge is outside the gates.

Figure 16-22 Approximate water, rail and highway access conditions at top US container ports



SOURCE: Cambridge Systematics, Inc.

16.9 Summary

The productivity of freight movement in the United States depends greatly on the ability to move commodities and goods in an efficient manner. When transportation networks become congested, efficient movement becomes difficult. Many components of the nation's transportation system are congested today, and will likely become even more congested in the future. As noted, the growth in demand for freight transportation is pressing the capacity of the freight transportation system. Solutions for alleviating this congestion include adding capacity where bottlenecks occur, improving the operational efficiency of vehicle movement, and better managing the demand for facilities and services through such strategies as pricing. Perhaps most important, investment in the nation's transportation infrastructure will be necessary to provide the capacity that will be needed to meet future freight demands. Given the nature of this infrastructure, this investment will need to come from both public agencies (for the highway system) and private firms. Without such investment, the economic costs associated with lost productivity due to congestion will grow and further hurt the economic competitiveness of the United States.

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17

System Security

Glen Harrison

17.1 Introduction

Given the vulnerability of transportation networks, providing security for the nation's transportation system is one of the most difficult challenges facing transportation and security organizations today, and it will likely remain so for the foreseeable future. (*1–5*) Transportation systems are highly valued targets for thieves and terrorists, as the systems are relatively easy to breach. Thefts affect a business's revenue, increase shipping costs, disrupt commerce, and ultimately mean higher costs for the consumer. Terrorist attacks disrupt lives, affect the economy, create fear, and leave lasting psychological effects on transportation workers, users of the transportation system, and the nation. (*6*)

This chapter discusses the issues relating to international cargo security, with emphasis given to public- and private-sector initiatives to improve cargo container and supply chain security. In section 17.2, the security problem and the challenges inherent in providing cargo security are examined, including a discussion of the relative roles of different agencies and participants. Section 17.3 describes different strategies for securing the supply chain and protecting cargo in storage and in transit. Section 17.4 concludes with thoughts on the challenges facing the transportation industry with respect to security.

17.2 The Security Problem and Challenge

The international cargo supply chain involves the coordinated management of the production, transport, distribution, and sale of goods. Supply chain partners include raw material suppliers, transporters, manufacturers, intermodal

Reprinted from *Intermodal Transportation: Moving Freight in a Global Economy.*

facility operators, distribution center managers, and retailers. More than 100 million cargo containers move through the international supply chain each year. Containers carry almost 90% of the manufactured goods shipped in international trade. (*7*) More than 11.6 million containers arrived at US seaports in 2006, an average of 32,000 containers per day. Goods packed in containers do not always come from a single source, as consolidators are often called on to combine goods from a number of sources in a single container for shipment overseas.

The magnitude of the transportation component of the supply chain makes it challenging to protect goods from origin to destination. For example, it is estimated that between $30 billion and $50 billion in cargo is stolen worldwide each year, with cargo theft in the United States alone reaching between $15 billion and $30 billion per year. (*8*) Cargo is most vulnerable when it is at intermodal, storage, or transfer locations, including ports, airports, terminals, cross-docking operations, and distribution centers. (*9*)

Table 17-1 provides an estimate of the different components of the US transportation system that play a role in the movement of freight. Not all of these components offer appealing targets for attacks. (*6*) For example, the vast majority of the approximately 4 million miles of roads in the United States carry low traffic volumes and serve no strategic economic purpose. The National Highway System, a 162,373-mile subset of the nation's roadways, consists of roads deemed important from the perspective of national connectivity, but any disruption to most of those roads would have no significant impact on economic activity. Only a small portion—450 bridges and 50 tunnels—of the hundreds of thousands of bridges and tunnels on the US transportation system is considered to be of strategic value. Similar observations can be made of other components of the nation's transportation system. But if the objective of an attack is to expose the vulnerability of the transportation system, the sheer extent of the nation's transportation system makes it difficult to protect from such an attack. (*6*)

The international nature of freight movement introduces additional complexity into transportation security. For example, a 2007 report from the US Department of Homeland Security (DHS) identified the following measures for enhancing the security of the international supply chain:

> Accurate data in the form of advance electronic information is necessary to support the risk assessment of the cargo. This information is needed early in the process to identify high-risk cargo before it approaches the United States. In the case of containers, the information is needed before vessel loading in a foreign port. Information must also come from reliable sources with, wherever possible, first-hand knowledge.
>
> Information must be appropriately shared amongst United States government agencies and our trading partners, while simultaneously being safeguarded from improper disclosure.

Table 17-1 System mileage within the United States (statute miles), 2008

System	Miles
Highway	4,042,778
Class I rail	94,082
Amtrak	21,178
Commuter rail	7,261
Heavy rail	1,623
Light rail	1,397
Navigable channels	25,320
Oil pipeline	169,422
Gas pipeline	1,530,012

SOURCE: Bureau of Transportation Statistics. *National Transportation Statistics*. US Department of Transportation. Washington DC, 2010.

> Secure cargo requires a procedure to ensure that the cargo conforms to the cargo information electronically transmitted to the authorities. This process connects first-hand knowledge of the cargo with the validation of the cargo information. This process also ensures that safeguards are in place to prevent unlawful materials (or persons) from being combined with the legitimate cargo. This part also includes a risk management process that includes the scanning and inspection of cargo identified as high risk prior to loading at foreign ports and, in some cases, after arrival at the United States port.
>
> Secure transit is a procedure designed to ensure that cargo remains secure as it enters and moves through the supply chain. Successful implementation requires a method of detecting if security has been compromised during transit and a response protocol to be enacted in the event of such a compromise. Securing the conveyances and transportation facilities used in the movement of commerce is critical to maintaining the security of the cargo while it is in transit.
>
> Improvements to security...must be addressed in a way that will ensure consistency and substantive improvements across the supply chain. This can only be achieved via engagement with the appropriate international organizations, e.g. the World Customs Organization (WCO) and the International Maritime Organization (IMO) and international trade partners in the development of standards. Standards are the only meaningful way that the government will be able to ensure that a high level of security across the supply chain can be expected and achieved. (*10*)

The extent of the security needs for international freight movement thus extends far beyond the borders of the United States.

A discussion of security threats to freight movements necessitates an examination of the types of threats that might occur. Table 17-2 shows the types of threats that were identified in a national study on improving the security of the nation's surface transportation system.[1] DHS ranks five threats to the supply chain, from highest to lowest, as follows:

- Weapons of mass effect (WME), including nuclear, chemical, biological, and radiological weapons and large quantities of explosives.
- Direct-threat contraband (e.g., components of WME, explosives) and direct-threat illegal immigrants (e.g., terrorist operatives).
- Indirect-threat contraband (e.g., money, drugs, weapons intended to contribute to terrorist activities).
- Economic illegal immigration (e.g., undocumented workers) and economic contraband (e.g., cigarettes, counterfeit CDs, etc.).
- Pilferage/theft. (*12*)

1 The European Commission has also undertaken substantive assessments of the vulnerability of Europe's transport network to different types of attacks, such as chemical, biological, radiological, and nuclear. (*11*)

Table 17-2 Possible threats against the US surface transportation system

Physical Attacks	
• Car bomb at bridge approach	• Attack on passenger vessel in port
• Series of small explosives on highway bridge	• Shooting in rail station
• Single small explosive on highway bridge	• Vehicle bomb adjacent to rail station
• Single small explosive in highway tunnel	• Bombing of airport transit station
• Car bomb in highway tunnel	• Bombing of underwater transit tunnel
• Series of car bombs on adjacent bridges or tunnels	• Bus bombing
• Bomb(s) detonated at pipeline compressor stations	• Deliberate blocking of highway-rail grade crossing
• Bomb detonated at pipeline storage facility	• Terrorist bombing of rail tunnel
• Bomb detonated on pipeline segment	• Bomb detonated on train in rail station
• Simultaneous attacks on ports	• Vandalism of track structure and signal system
• Terrorist bombing of waterfront pavilion	• Terrorist bombing of rail bridge
• Container vessel fire at marine terminal	• Explosives attack on multiple rail bridges
• Ramming of railroad bridge by maritime vessel	• Explosive in cargo of passenger aircraft
Biological Attacks	
• Biological release in highway tunnel	• Anthrax release in transit station
• Anthrax release from freight ship	• Anthrax release on passenger train
Chemical Attacks	
• Sarin release in multiple subway stations	• Physical attack on railcar carrying a toxic chemical
Cyber and Command, Control, and Communication System Attacks	
• Cyber attack on highway traffic control system	• Sabotage of train control system
• Cyber attack on pipeline automated control system	• Tampering with rail signals
• Attack on port power and telecommunications facility	• Cyber attack on train control center

SOURCE: As reported in *Improving Surface Transportation Security, A Research and Development Strategy,* Washington DC, National Academy Press, 1999. Originally in US DOT *Surface Transportation Vulnerability Assessment,* Final Report, Washington DC, May, 1998.

FreightWatch International tracks trends in cargo theft in the United States. (*13*) More than 600 cargo thefts from full truckload trailers, containers, or warehouses occurred in the United States in 2008, representing a 13% increase from 2007. Major commodity groups for these thefts included electronics (24%), building and industrial materials (17%), food and drink products (16%), and home and garden supplies (9%). Three significant trends in cargo theft in 2008 were also identified. First, theft of pharmaceutical shipments increased significantly. Second, thefts focused more on high-end brand product lines. Third, major metropolitan areas that serve as intermodal transfer points were the major centers for cargo theft, primarily Los Angeles, Dallas/Fort Worth, Miami, Atlanta, and Memphis.

The perpetrators of cargo theft are usually associated with three major groups. (*14*) The first group consists of employees who work for the intermodal facility (port, warehouse, etc.), shipper, or transporter. They either steal the cargo directly or provide information to outside individuals or organizations that target the cargo. The second group includes small gangs of cargo thieves who target trucks in transit or at warehouses. The third—and most sophisticated—group involves organized crime syndicates. They usually have insiders providing information on specific shipments of high-value goods that are moving through the supply chain, and they have the ability to plan the theft systematically, transport the stolen goods, and sell them in the United States or overseas.

Different types of thefts have their own special characteristics. Warehouse thefts, for example, often involve disabling the alarm systems by cutting the communications lines or by entering an alarm passcode acquired through illicit means. (*15*) Thefts of tractor-trailer shipments usually take place at rest stops, truck stops, or unsecured terminals, when the driver is away from the truck. The trailer is detached from the truck and connected to another tractor, or the entire tractor trailer is stolen. In both cases, the cargo is usually driven a short distance before being transferred to another tractor-trailer or warehouse. (*16, 17*)

If goods are removed from a container in transit, the theft is difficult to detect unless the container has an electronic seal or an alarm communications system. The loss of goods from the container may not be discovered until the container reaches the consignee, at which time it is too late to determine when and where the theft took place in the supply chain.

Theft losses not only include the costs of the goods stolen, but also the costs associated with the disruption in the production process and resulting reductions in retail sales. Costs incurred also include those for reordering the product, shipping replacement goods, filing claims on the loss, and insurance payouts. In the end, however, it is the consumer who bears the increased costs of thefts through higher prices for purchased goods.

The supply chain also provides opportunities for the transport of materials and individuals associated with terrorism. Stephen Flynn and Jeane Kirkpatrick identify three major differences between the motivation and operations of cargo thieves and those of terrorists. (*18*) First, terrorists are likely to plan for a one-time operation that will disrupt and damage the supply chain, while cargo thieves focus on the diversion of cargo from a continuously operating supply chain. Second, terrorists are likely to focus on a weak link in a brand name product supply chain that is involved in US government security initiatives because these shipments receive reduced security attention as they enter the country. Third, the disruption by terrorists of a supply chain that is part of a government-sponsored security program will call into question the validity and viability of security initiatives, with the result that attempts at disrupting such supply chains would initiate a review of the entire international supply chain security system.

17.3 Supply Chain Security Initiatives

Initiatives to secure the supply chain have been undertaken by many different groups and organizations, including companies that want a secure supply chain for their product line or retail chain, private-sector associations, governments, and international organizations. An important aspect of these initiatives is that supply chain security must be examined for both physical threats and threats to information support systems. Physical security includes the security of the container itself; the security of the vehicle and container or trailer as it moves through the supply chain; and the security of the support infrastructure at the factory, intermodal facility, or retailer. Information security includes the protection of electronic systems that track shipments, information about the shipment's contents and schedule, security system access codes, security management plans, personnel and financial records, and shipping and customs information. Cargo information (i.e., shipping documentation) and financial information move through the supply chain as much as the cargo itself. Customs and Border Protection (CBP) has a layered security program that uses this information to evaluate cargo shipments at the port of embarkation and debarkation, along with other information efforts that evaluate the complete supply chain.

17.3.1 Individual Supply Chains

Producers and retailers work with their suppliers, freight forwarders, and shippers to ensure the security, integrity, and efficiency of their supply chains. Even though a company may not control its entire supply chain, it needs to know and work with its supply chain partners to ensure the quality and security of the products throughout the supply chain. Security standards are the major means of ensuring that security efforts meet security expectations; they are enforced through periodic reviews and audits of supply chain partners. (*19*)

A more secure supply chain can be achieved by relying on carriers and logistics companies that provide secure supply chains from origin to final destination. Some US third party logistics (3PL) companies, for example, have expanded their operations into China and other developing nations where manufacturing is concentrated. YRC Worldwide, Schneider National, Con-way Freight, and J. B. Hunt Transport Services have all invested in operations in China. The main reason for this investment is to better capture the international logistics market for manufactured goods shipments from the source location to the final destination. While these 3PLs only serve a small part of the market, they do provide the business practices and infrastructure that support the secure transportation of manufactured goods from source to destination. (*20*)

17.3.2 Private-Sector Associations

Some companies have established their own set of processes and protocols to increase supply chain security. The Transported Asset Protection Association (TAPA) is an example of such an association. TAPA represents companies that produce compact, high-value goods. (*21*) TAPA has defined a set of security standards and has a certification program that uses an audit checklist of freight distribution facilities that have contracts with association members. Each freight forwarder or logistics facility is audited and rated based on the elements in the freight security requirements checklist. The results of the audits are made available to TAPA members so that they can determine the level of security available at freight forwarders or logistics companies.

The Strategic Council on Security Technology, an industry-based group focused on improving supply chain security and efficiency, developed the Smart and Secure Tradelanes initiative based on container tracking systems. (*22*) These tracking systems are accessible to all supply chain partners and government security agencies and provide in-transit visibility that allows a shipment to be monitored as it moves through the supply chain.

17.3.3 National Governments

National governments have passed laws and instituted policies that impact the security of international cargo supply chains. The United States is at the forefront of instituting policies to increase the security of international cargo supply chains with United States destinations. One such initiative is the Customs-Trade Partnership Against Terrorism (C-TPAT), a voluntary program involving businesses and CBP. CBP inspectors work with supply chain partners to develop effective security plans for individual supply chains from overseas origins to US destinations. Once implemented, these measures are periodically audited by CBP to ensure the maintenance of the supply chain security standards. (*24*) The Free and Secure Trade (FAST) program is a similar effort between the United States and its North American Free Trade Agreement (NAFTA) partners of Mexico and Canada. (*25, 26*)

One of the most effective programs is the Container Security Initiative, which places CBP inspectors in foreign ports that are major origins for shipments to the United States. (*27*) Documentation on all containers bound for the United States is reviewed by CBP inspectors. Potentially high-risk containers are scanned by nonintrusive inspection technologies, such as x-ray, gamma ray, and radiation detection devices. The resulting data are reviewed before the container is allowed to be loaded on the US-bound vessel. If the detection devices produce an alarm, local government authorities conduct a physical inspection of the container. As of 2009, the Container Security Initiative had been implemented in 58 ports in North, Central, and South America; the

Caribbean; Europe; Africa; the Middle East; and Asia. About 86% of the containers shipped to the United States are covered by the initiative. The United States reciprocates by having customs inspectors from Japan and Canada stationed in US ports to inspect cargo containers bound for those countries.

The Secure Freight Initiative is a follow-up to the Container Security Initiative. This initiative is a test for new, nonintrusive inspection technologies. (*28, 29*) In coordination with the US Department of Energy (DOE) and the US Department of State, the DHS has provided advanced nonintrusive inspection technologies, such as radiation detectors and container imaging equipment, to six foreign ports (Port Qasim, Pakistan; Puerto Cortes, Honduras; Southampton, United Kingdom; Port Salalah, Oman; the Gamman Terminal at Port Busan, South Korea; and the Brani Terminal at the Port of Singapore). Containers bound for the United States are scanned for radioactive substances and x-rayed to obtain an image of their contents. The images, sensor information, and shipping documentation are sent to the CBP National Targeting Center in the United States, local Container Security Initiative staff at the port, and host country customs officials for review and analysis to determine if the container contents present any potential threat. All concerns about the container are resolved by local authorities at the foreign port before the container is loaded on a ship bound for the United States. (*30*)

The DOE's National Nuclear Security Administration's (NNSA) Megaports Initiative is a complementary program to the DHS efforts at foreign ports. The purpose of this initiative is to screen containers for nuclear and other radiological materials. The initiative installs radiation detection systems—including radiation portal monitors, computer and camera equipment to collect and transmit alarm information for analysis, and handheld equipment that can be used to conduct secondary inspections—to find and identify radioactive sources in a container, in a vehicle, or on a person. Training and equipment maintenance are included with the program. The screening equipment can be used for imports, exports, and transshipment containers. Information from the detectors is transmitted to local customs officials and the National Targeting Center in the United States. Currently, the initiative is in place at 19 ports, including all of the Container Security Initiative ports. The eventual goal is to install the radiation equipment at 70 ports in 35 countries. (*31*)

17.3.4 International Organizations

International organizations are also involved in actions to improve cargo supply chain security. Such organizations fall into two groups: groups that establish standards and guidelines for security efforts, and international agencies that adopt policies and programs that are adhered to by signatory governments.

The International Organization for Standardization (ISO) is an example of the first type of international organization. A network of the national standards institutes in 160 countries, ISO has developed security management standards for supply chains. These standards provide guidelines for supply chain security processes and enhancements for finance; manufacturing; information management; and facilities for packing, storing, and shipping cargo between transport modes and locations. ISO provides guidelines and procedures for supply chain partners to establish, document, implement, maintain, and continually improve security management systems for supply chains. (*23*) The implementation of this system is illustrated in Figure 17-1.

The International Maritime Organization (IMO) is an example of an international agency with policy-making authority. A specialized agency of the United Nations, IMO has 169 member states focused on safety, environment, legal matters, technical cooperation, security, and the efficiency of shipping. In 2002, IMO adopted the International Ship and Port Facility Security Code (ISPS Code), which contains security-related requirements for governments, port authorities, and shipping companies, as well as guidelines on how to meet those requirements. (*32*) The focus of this effort is on assessing vulnerabilities and threats, implementing security measures to reduce the opportunities for terrorism and theft, enhancing responses to incidents, and providing information sharing among the partners. The US Coast Guard (USCG) is the lead agency for the coordination of ISPS Code activities with other nations. USCG International Port Security Liaison Officers coordinate with international trade partners on their security plans and on the implementation of security measures.

Figure 17-1 ISO security management system

17.4 Efforts to Increase Supply Chain Security

Actions can be taken at points along the supply chain to enhance shipment security. These actions can include cargo tracking, container security, information and communications security, physical security at fixed facilities, personnel security, security policies and procedures, and changes in business practices. This section will discuss actions that are being taken to increase security in each of these areas. (*33, 34*)

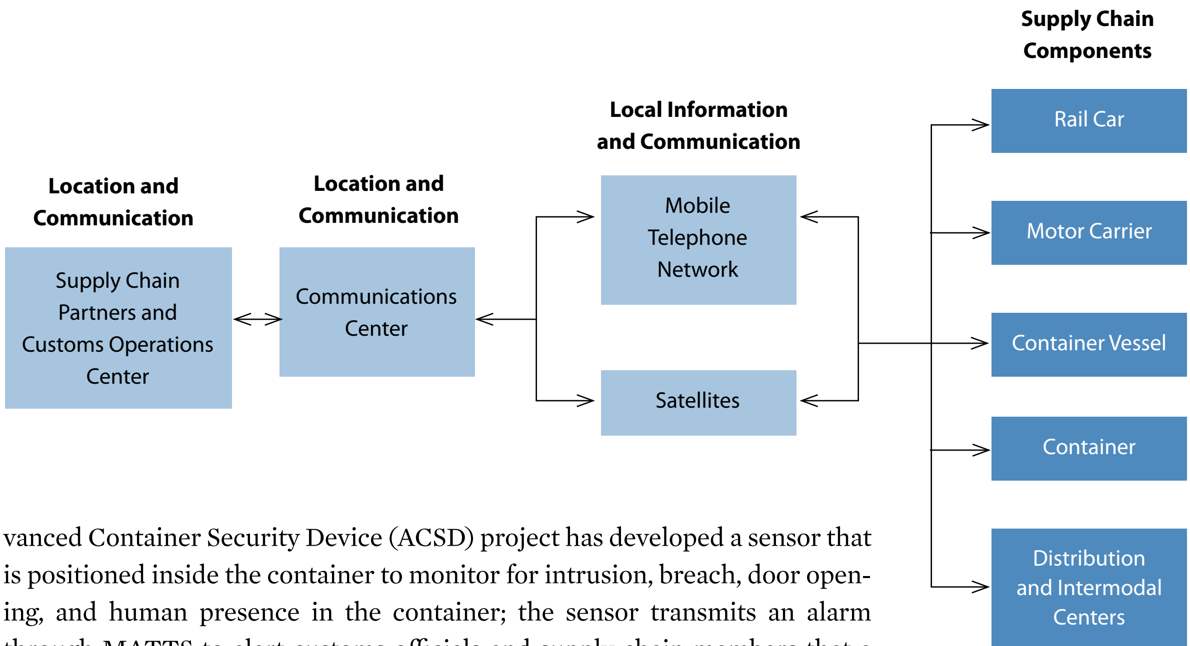
17.4.1 Cargo Tracking with Smart Containers

The implementation of cargo tracking systems provides in-transit visibility of the cargo as it moves through the supply chain. Electronic data interchange (EDI), web-based electronic freight management systems, radio frequency identification (RFID) systems, the global positioning system (GPS), and satellite and mobile telephone communications systems can be used to track cargo in transit and at fixed facilities in the supply chain. Containers, pallets, and individual packages can have active or passive RFID tags or bar codes that facilitate information transfer as the cargo moves through the supply chain. Truck trailers, railcars, barges, and ships can be tracked with the use of active RFID tags, GPS, and satellite and mobile telephone communications systems. The location and cargo condition data can be electronically transferred from the shipment to an information management system of the supply chain members and customs agencies. Cargo can then be tracked using the systems of the individual supply chain members. A cargo tracking system is illustrated in Figure 17-2.

Total in-transit visibility has not been achieved in most supply chains because of the many different participants in the supply chain who have different levels of technology for tracking cargo and varying abilities to provide that information to other supply chain members. The tracking systems used by members of the supply chain are not always integrated or interfaced into a single system that all parties can access, which means supply chain members must access different tracking systems to determine the location and status of their shipments. Future advances in electronic freight management systems will enable more data sharing and increased in-transit visibility through a single data interface. (*35*)

The DHS Science and Technology Directorate is sponsoring a number of container monitoring, alarm, and communications initiatives to increase the security of containers as they move though the supply chain. The Maritime Asset Tag Tracking System (MATTS) has been developed and tested with container shipments between Japan and the United States. MATTS provides a global communications and tracking system that can be used to track a container between its loading and unloading locations. The complementary Ad-

Figure 17-2 Cargo tracking system



vanced Container Security Device (ACSD) project has developed a sensor that is positioned inside the container to monitor for intrusion, breach, door opening, and human presence in the container; the sensor transmits an alarm through MATTS to alert customs officials and supply chain members that a security issue has been detected. The information transmitted includes the container and the category of occurrence.

ACSD also has an interface to allow for additional security sensors to detect the presence of radiological, nuclear, chemical, and biological items. Hybrid composite containers with imbedded sensors are also being developed. The composites are stronger and lighter than steel, allowing a larger payload in a more secure container. Secure cartons are being developed that will send an alarm signal in the event of tampering. Secure pallet wrapping material with fluorescent tamper indicator capabilities is also being developed. (*36*) All of these technologies will be moving from the prototype and test phase into the commercial sector within the next few years.

17.4.2 Container Locks and Seals

Containers, trailers, railcars, and air cargo containers moving through the supply chain are typically locked and sealed, and the seal numbers are sent to supply chain members as a part of the information flow though the supply chain. Seals are inspected as cargo containers, trailers, railcars, or air cargo containers enter or leave each facility in the supply chain, and if there is any evidence of tampering, the supply chain partners and the authorities are notified.

Electronic cargo seals, both passive and active, can be used to transmit information on container tampering. Passive seals are interrogated by readers placed at points along the supply chain, while active seals send a signal at the moment tampering is detected. (*37*)

17.4.3 Information and Communications Security

The security of a supply chain depends on both the physical security of the facility and the security of information and communications systems. Secure supply chain information and communication systems for personnel, cargo tracking, manifest, and shipping documentation are very important, as such systems can thwart cargo theft attempts that rely on information about shipment contents and timing. Because secure information and communications systems reduce the vulnerability of the cargo supply chain, good practices include restricting access to computer and document centers to authorized personnel, requiring user identification and passwords for access to the systems, and storing sensitive documents in locked cabinets. Firewall and antivirus software on computer systems can also serve to limit access to information systems. Event logs are useful in tracking all electronic transactions.

17.4.4 Physical Security for Fixed Facilities

Fixed facilities along the supply chain include intermodal and intramodal facilities (seaports, airports, rail yards, truck terminals, and barge terminals), manufacturer distribution and receiving operations, and wholesale and retail distribution centers. Every fixed facility through which cargo and information related to the cargo pass requires a high degree of security. Physical security measures at these locations include the security infrastructure, electronic and mechanical means of deterrence, lighting, and surveillance systems. (*34, 38*)

Secure facilities have concentric, layered, and varied types of security measures that discourage unauthorized access and detect any unauthorized entrance or theft of property from the facility. Physical security infrastructure measures include separating the facility from parking lots and public spaces, implementing security checks or card readers at entrance and exit points, and installing security lighting to improve surveillance capabilities and deter unauthorized activities. Within the facility itself, additional access restrictions often include separate fenced or walled areas that require further security checks and intrusion detection systems for deterring unauthorized entrance, detecting security breaches, delaying any intrusions into the facility, and notifying authorities of an intrusion. Closed-circuit television systems are used to detect security related activities, assist in situational analysis for a response, and preserve images for review and analysis at a later time.

17.4.5 Personnel Security

Security requirements for transportation workers and others—including onsite staff, contractors, transportation operators (truck, rail, air, and vessel), customers, and visitors—are an important element of a comprehensive secu-

Embedded Technologies to Secure the Supply Chain

"Our supply-chain logistics managers are using technology to automate the functions relating to the capture of information on cargo and inventory. They have deployed a panoply of 'bolted-on,' but often not 'embedded,' technologies—computerized databases and information, communications and sensing systems equipped with radio frequency identification (RFID), GPS and other sensors—to track shipments, manage inventory, and locate assets and cargo in-transit. These technologies, along with 'intelligent adaptive' software systems for demand forecasts, have allowed enterprise resource plan managers to avoid risks of unpredictable shortages, bottlenecks, and oversupplies.

"Cutting edge developments in nano- and bio-tech and in artificial intelligence have not only created new opportunities for the growth of tracking and surveillance operations, but have also stimulated new applications in fusion of RFID, making it even more pervasive:

- Fusion of robotic devices with RFID, GPS and other sensors has allowed robots today to perform hazardous tasks and conduct security sweeps in addition to many other civilian dual-use operations. . . .
- Application of artificial intelligence to the design of security-embedded infrastructures is another facet of today's emerging technology-fusion capabilities. . . .
- Developments in nanotechnology have also helped with proliferation of embedded sensors and tracking technologies. . . .
- Fusion of bio-tech sensors and nano devices has given rise to a host of technologies such as ZigBee that foretell potentially radical structural changes in how technologies are embedded. . . ."

SOURCE: Barami, B. Embedded Technologies to Secure the Supply Chain from End-to-End. Presented at the International Society of Logistics 2004 Conference, Norfolk, VA, Sept. 2, 2004.

rity program. Employees and contractors are screened before hiring, and security training and identification cards are required of all employees and contractors. The Transportation Worker Identification Credential (TWIC) is being implemented by DHS for all personnel who work at ports. (*39*) Airports have similar security card requirements for workers in cargo and baggage areas. Customers and visitors are restricted to areas that have no access to sensitive information or cargo.

Access control cards with encoded information identifying the card holder enable management to know the location of staff in the facility. It also facilitates a layered security approach by limiting access to specific areas for those who have authorization. If an incident or theft occurs, management has a record of which staff members were in the proximity of the incident.

17.4.6 Security Policies and Procedures

A security policy establishes strategic objectives and priorities for an organization, assigns the responsibility for security management within the organization, and defines responsibilities and expectations for staff. Security procedures are instructions on how to implement the security policy. (*34*)

The facility's lead security manager is responsible for developing and implementing security procedures. The security manager and the security staff review the business procedures, physical facility, processes, and shipping and storage operations to identify areas that may be vulnerable to theft, sabotage, or terrorist attack. They develop facility restoration plans, which would be implemented in response to a terrorist attack or a weather emergency, and security plans for the facility.

A facility security plan typically considers several issues. First, it identifies potential threats, vulnerabilities, and consequences. Second, it identifies the priorities for protection of assets. These priorities include people (staff, contractors, customers, visitors), physical assets (buildings, inventory, equipment), electronic and paper information (shipments, inventory, staff), and supply chain processes (outbound and inbound shipping, cross docking, storage). Third, the plan guides the development of necessary security measures and establishes a funding mechanism for implementing and maintaining the security systems and procedures. Fourth, the plan encourages the implementation of the physical security infrastructure and procedures at the facility. Fifth, the plan proposes tactics for coordination between local law enforcement, emergency response, and fire protection organizations, as well as appropriate federal agencies. The first-responders need to be aware of the layout of the facility, the types of cargo in the facility, and the presence of any hazardous materials. An example of this activity is port terminal managers working closely with USCG in the development of port security plans. Sixth, it includes recommendations for periodic reviews of the security measures, as well as practice exercises aimed at identifying weaknesses in the security plans and improving the response time of staff during an actual emergency. These reviews and exercises may result in changes and improvements in the security plans.

17.4.7 Changes in Business Practices

The increase in the potential for cargo theft and terrorism has provided impetus for companies to rethink their supply and inventory strategies. (*40*) These new strategies consider the trade-off between the cost of a highly-integrated, lean supply chain and resiliency in the supply chain.

Many companies have adopted the core supplier concept to create strong, integrated relationships between supply chain partners. The result is a reduction in the number of alternative suppliers in the supply chain. However, security concerns have challenged the strategy of relying on a single overseas, low-cost supplier for their goods. While some companies continue to depend on an offshore supplier for most of their goods, they have also established relationships with supplier(s) in North America for a small portion of their goods, with the understanding that if the overseas supply chain is disrupted, the North American supplier can increase production to satisfy the demand. Sourcing from the North American suppler marginally raises the overall cost for the products, but the increased cost is offset by the assurance of continued supply.

Lean supply chains are built on the premise that there should be no redundancy or excess inventory. The uncertainties in the complex international supply chains have required some companies to increase the amount of safety stock kept in inventory—i.e., raw materials from an overseas supplier or finished products that are made in the United States using raw materials from an overseas supplier. The increase in safety stock results in additional costs for storage space, inventory, staffing, and insurance, but the trade-off is the assurance of continued supply to the customer.

17.5 Conclusions

Although security in the cargo supply chain has increased, a number of improvements are still required. Greater use of sensors on containers and tracking websites by supply chain partners are important technologies that will enhance security, but there is a need for more integrated in-transit visibility over the complete supply chain using one system, instead of individual systems of different supply chain partners. This visibility would increase cargo movement security and efficiency and reduce supply chain operations cost. The introduction of a set of international standards that would include data requirements for the shipment (container, consignee, consignor, shipper, carriers, ports, manifest), security performance (visibility, detection, deterrence), communications (satellite, mobile telephone, RFID systems), and sensors (radiological, nuclear, chemical, biological, human) would help facilitate the development of technologies to support secure supply chains.

The ISPS Code and the Smart and Secure Tradelanes initiative provide a framework for secure cargo container movements through and between international ports. The United States has built on these efforts with its C-TPAT initiative, Container Security Initiative, Secure Freight Initiative, and Megaports Initiative. The information sharing from these initiatives is bilateral between the United States and the host port nation. A broader agreement on container security would allow the information sharing to be expanded to multiple government security agencies. This change would reduce the need for countries to place their security staff in different ports all around the world, while increasing the security of the international cargo supply chain.

A multitude of security initiatives have been instituted by private companies, industry organizations, national governments, and international organizations. This chapter has touched on just a few of these. Improved coordination between these different initiatives would ensure that they complement, rather than duplicate and compete with, each other.

International supply chains involve multiple countries and international jurisdictions. A container is shipped by motor carrier or rail from the manufacturer to a port or airport in one country. It is then transported by air or sea, potentially through a number of ports or airports in different countries, to a destination country. The container is transported by rail or motor carrier, or both, in the destination country. A security incident can occur in any of these locations. When an incident does occur, the container communications system sends a signal to supply chain members and appropriate authorities about the nature and location of the incident. The results of the response are documented for supply chain members and other government authorities. All of these actions require that international agreements be in place between the different nations, international organizations, and supply chain partners so that they can know how to respond and what the expected outcome will be.

Increased cargo supply chain security must be done within a cost-effective framework. Security measures cannot be implemented to a level that would restrict the flow of commerce or greatly increase the cost of goods to the consumer. Continued innovations in sensors, tracking, communications, and non-intrusive inspection technologies will increase cargo security, while allowing cargo to continue to flow in a cost-effective manner. A number of economic benefits of increased supply chain security have been identified by others. For example, Michael Wolfe and Dan Inbar estimate that the introduction of smart containers with tracking and communications systems would result in savings of $10 billion per year, and they, together with Stephen Flynn, predict that benefits will result from fewer delays and misrouting of shipments, improved just-in-time processes, reduced inventory, increased intermodal container management efficiency, reduced theft and diversion of cargo, lower insurance rates, increased in-transit visibility, and better defense against the prospect of the breach of a container for terrorist purposes. (*41, 42*) Jim Giermanski identifies additional benefits as an increase in the number of smart containers that can be moved through the CBP's "green lane" program, which improves the speed of the container through the port and allows customs to concentrate on a smaller number of target containers. (*43*)

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18

Freight Transportation and the Environment

James J. Corbett and James J. Winebrake

18.1 Introduction

The movement of goods and products from origin to market is intrinsically coupled with the environment through economic geography. The term *freight* represents the longer-haul movement of property and resources to facilitate the trade of commodities.[1] In modern contexts, freight is a general term for transport of "anything carried by sea or land; 'goods' in transit or being transported by rail, road, air or sea." *(1)* As civilizations traded more goods over longer distances, the expanding network of water, road, and rail services resulted in greater interaction with the environment. Explorers and traders returning to markets with raw or processed products faced environmental constraints (terrain, weather, ecology) that largely determined which paths across land and water were most passable and thus destined to become trade routes. Water routes offered the earliest advantages for heavy cargo because the goods could be transported in ships in greater volume. On land, the best routes widened into wagon roads, and the best of these evolved into today's major roadways and highways. Later, the weight-carrying advantages of railways (initially part of a roadway laid with rails of wood, and later with iron or steel) complemented the highway network for longer distance trips.

Today, international goods movement is a critical economic activity that relies on a global transportation system of ocean and coastal routes, inland waterways, railways, roads, and air freight. In some cases, the freight transportation network connects locations by multiple modal routes, functioning as modal substitutes or complements. A primary example is nontransoceanic container-

1 The word *freight* itself derives from an older word *"fraught,"* which referred to the hire of a boat for movement of owned acquisitions or property.

ized shipping, where the shipper or logistics provider has some degree of choice whether to move freight between nations by road, rail, water, or combinations of these modes. International maritime transportation, on the other hand, is more commonly a complement to other modes of transportation. This is particularly true for intercontinental containerized cargoes and for liquid and dry bulk cargoes, such as oil and grain. International shipping connects roads, railways, and inland waterways through ocean and coastal routes.

As global trade expanded greatly over the past five decades, so too did governmental laws and regulations relating to environmental quality. The seminal environmental legislation in the United States, the 1969 National Environmental Policy Act (NEPA), requires that a systematic assessment of environmental impacts and potential mitigation strategies be undertaken for projects where federal monies or federal action is required. This law was followed by numerous other environmental laws and regulations at the international, national, state, and, in some cases, local levels that have put infrastructure and operational decisions under environmental scrutiny. It is very difficult for a public agency or a private firm to build a major facility today without going through a significant environmental assessment process, usually resulting in some form of mitigation action to reduce expected environmental impacts. And public policy makers are increasingly turning to the transportation sector for strategies to mitigate or reduce the impact of a modern economy on the environment, such as reducing carbon dioxide (CO_2) emissions from motor vehicles in order to reduce the emissions that contribute to global climate change.

In today's society, those responsible for providing transportation infrastructure and services must be aware of the types of environmental impacts that are associated with the movement of people and goods and look for possible mitigation strategies. This is certainly true for freight movement. Engineers consider not only how to improve navigation by deepening waterways through locks and dams or dredging, but also how to protect wetland ecosystems in the process. Highway planners often plan new and expanded highway networks, but do so within the context of community and regional land use goals. In other instances, transportation officials seek to influence travel behavior through such strategies as pricing (e.g., congestion charge in London, England). Diesel power and propulsion, the driving engine of freight, is becoming cleaner as a result of fuel quality improvements and better emissions control systems. Carriers are reducing vehicle speeds and modifying designs to lessen resistance and drag so that each cargo movement consumes less energy (at least per unit cargo). Finally, logistics supply chains are rebalancing mode shares and inventories in the recognition that reliable and timely deliveries need to achieve environmental benefits.

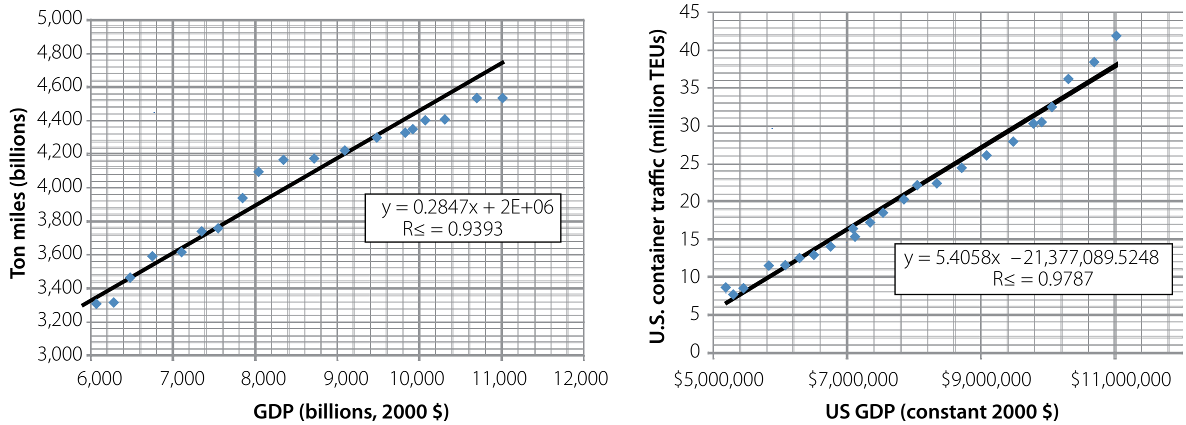
This chapter provides a broad overview of environmental concerns and goals related to freight transportation. Section 18.3 presents examples of the types of environmental impacts that are of concern to the freight industry and communities and examples of programs aimed at reducing environmental harm. The next three sections focus on pollutants affecting three of the most important environmental qualities linked to freight transportation—air, water, and noise. Each section discusses the characteristics and sources of the pollutant, and the types of strategies that can be used to reduce its impact. Section 18.7 addresses the process that is used to consider environmental impacts, and Section 18.8 discusses the concept of environmental management systems.

18.2 Freight, Economic Growth, and Environmental Impacts

Freight transportation is often called the lifeblood of the global economy. This is particularly true in western countries, where freight growth is closely aligned with increases in gross domestic product (GDP), as shown in Figures 18-1 and 18-2. These figures depict the relationship between GDP growth and freight transportation over the past few decades. Freight infrastructure, and the movement of vehicles and materials over this infrastructure in support of economic growth, can have significant effects on the natural and community environment within which these activities occur. For example, pollutant discharges from vessels and vehicles have important consequences for human and ecological health. The construction of facilities such as tracks, intermodal facilities, and freight distribution centers could disrupt nearby environmental resources, as well as burden neighboring communities by creating additional truck traffic and its associated disruptive impacts. These possibilities present challenges to those responsible for operating freight facilities and services, as well as for public agencies charged with permitting such facilities and minimizing their environmental impacts through regulation.

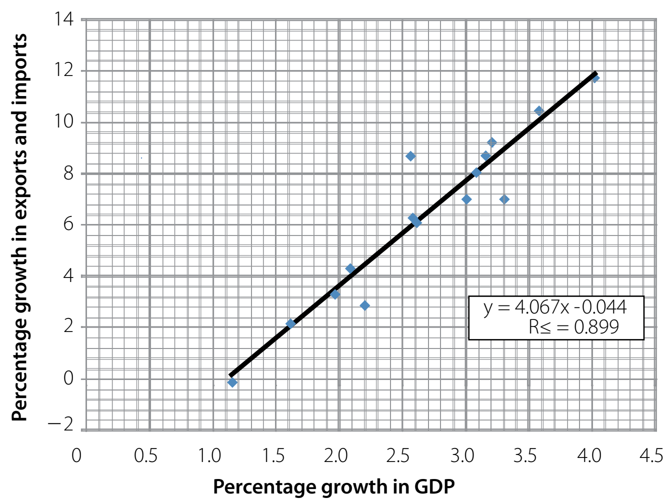
There are few national databases that estimate the freight sector's contribution to environmental quality (with the exception of air emissions discussed later). For example, it is unknown how freight transportation affects water quality or the number of wetlands that might be affected through facility design. The US Coast Guard keeps track of the number of spills that occur in US waters, but there is no assessment of the environmental impact of such spills (unless the spill is so major that the local ecology is seriously affected). Much of what the transportation profession looks at with respect to potential environmental effects relates to site-specific linkages between specific project characteristics and affected environmental resources. The remainder of this chapter will focus on these types of impacts, except in the case of air quality, which has a well-established methodology and analysis process associated with estimating emission levels at a range of geographic scales.

➤ **Figure 18-1** Relationship between cargo shipments (ton-miles) and container traffic (TEUs) and GDP for the United States from 1965 to 2006



SOURCE: Cited references *2* and *3*.

➤ **Figure 18-2** Relationship between economic growth and growth in exports and imports (1992 to 2006) in Organization for Economic Cooperation and Development countries, showing elasticity of this relationship. (Note that each percentage in GDP growth is correlated to about a 4% growth in trade.)



SOURCE: Derived from cited reference *4*.

18.3 Characteristics of Freight-Related Environmental Impacts

18.3.1 Types of Environmental Impacts

The legal and regulatory framework for considering environmental effects varies by country and by state. Some states, such as California, have strong environmental laws and ordinances that are even more demanding than federal legislation. Thus, the types of environmental considerations that might be appropriate for a given situation will likely vary by project and environmental circumstance, as well as by jurisdictional requirements. Some of these considerations might include impacts relating to:

- Noise and vibration
- Land use compatibility/zoning
- Local traffic impacts
- Socioeconomic characteristics of the community
  - Environmental justice
  - Community impacts
- Air pollutant emissions (including greenhouse gases)
- Water quality
- Energy consumption
- Hazardous waste contamination
- Natural resources
  - Wildlife habitat
  - Vegetation
- Cultural resources
  - Historic structures
  - Archaeological sites
  - Landscapes and traditional cultural properties

A recent review of *state government programs* aimed at supporting environmental mitigation strategies associated with freight movement illustrates the range of environmental issues that could affect the freight industry. *(2)*

California: Grants are provided to private companies and public agencies "to clean up heavy-duty engines beyond that required by law through retrofitting, re-powering or replacing their engines with newer and cleaner ones." Natural gas combustion engines are eligible for grants administered through local air pollution control districts. The program is funded by fees on new tire purchases ($1.75 per tire), vehicle registration fees, and smog abatement fees ($12 per new vehicle).

Texas: A comprehensive emissions reduction plan (Texas Emissions Reduction Plan—TERP) has been implemented with incentive grants offered for strategies that reduce emissions. Included in this program are grants for heavy duty vehicles, nonroad equipment, marine vessels, locomotives, stationary equipment, refueling infrastructure, on-site electrification and idle reduction infrastructure, on-vehicle electrification and idle reduction infrastructure, and rail relocation and improvement.

Oregon: Tax credits are offered for 35% of the cost of installing diesel emissions controls. The state also sells truck auxiliary power units, which trucking companies can purchase with a low-interest loan.

Pennsylvania: Matching grants of up to $5,500 are provided to small businesses for the purchase of pollution prevention equipment. Truck owner-operators and small trucking companies are eligible for the grants.

Wisconsin: Payments are provided for up to 70% of the cost of installing idling reduction equipment.

Arkansas and Minnesota: Small business loans are available to purchase truck emissions control systems.

Port authorities have also been an active participant in environmental mitigation programs. Some of the more comprehensive programs include those at the ports of Los Angeles, Long Beach, and Virginia.

The ports of Los Angeles and Long Beach adopted an air quality plan having a target of halving pollutant emissions by 2010. The plan includes incorporating environmental protections in all new or modified leases with shipping companies, each of which would include some or all of the following strategies:

- Energy
  - Slower speeds for ships within 40 miles of shore.
  - Increased use of alternative marine power (AMP), which allows ships to turn off diesel engines while at dock and plug into electrical power. Los Angeles was the first port in the world to use AMP for container ships. All major terminals at the two ports were to be equipped for AMP by 2010.
  - AMP for tugboats.
- Emissions
  - Use of low-sulfur fuel at port, rather than the usually used bunker fuel.
  - Use of technologies that reduce emissions, such as fuel emulsification, slide valves, and cylinder lubricating systems.
  - Repowering and retrofitting harbor craft and equipment to control emissions or use alternative fuel. Within five years, all equipment will meet or exceed the highest Environmental Protection Agency (EPA) emissions standards.
  - Replacing dirty locomotives with clean diesel locomotives.
  - Reducing truck emissions by replacing older trucks; underwriting programs for independent truckers. Within five years, the entire fleet of trucks is to be replaced.
  - Truck idling limits.
  - Use of green ships, which combine a number of environmental technologies.
- Institutional
  - Fines for failure to comply with any agreement or requirement.
  - Ambient air quality monitoring in and around the ports; air emissions inventory.
  - Cooperative environmental programs with the Port of Shanghai.

The steps taken by the Port of Virginia include the following:

- Creation of an Environmental Management System (EMS) that targets air and water quality improvements and energy efficiency at Newport News Marine Terminal, Norfolk International Terminals, and Portsmouth Marine Terminal. (Environmental management systems will be discussed in more detail in a later section.)
- Implementation of several strategies specifically targeted at reducing air and water pollutant emissions, including: (a) a new procurement policy that requires new cargo handling equipment to use the lowest emitting engine available on the market; (b) a low interest or extended-term loan program that encourages the purchase of low emission trucks; (c) use of ultra-low sulfur diesel fuel port-wide; and (d) use of treatment devices, structures, or ponds to removed polluted water discharges.
- Investment in open space and wildlife habitat preservation, as well as creation of wetlands.

Another evolving concept in environmental stewardship that could have far-reaching consequences to freight transportation is sustainable development or sustainable mobility. Sustainable development focuses on providing for economic growth in the most environmentally sound and equitable manner. London's recent freight transportation plan is a good example of how this concept can be applied to freight transportation. Sustainable freight distribution is defined in the London plan as,

> the balanced management and control of the economic, social, and environmental issues affecting freight transport that: (1) complies with or exceeds environmental standards, regulations or targets aimed at reducing emissions of climate change gases, improving air quality and minimizing impacts from accidents, spillages or wastes, (2) ensures freight is run efficiently, reduces unnecessary journeys, minimizes journey distances and maximizes loads with effective planning, (3) complies with labor, transport and human rights standards and regulations ensuring that employees and communities affected by freight can function in a healthy and safe environment, and (4) minimizes the negative impacts of freight activities on local communities. *(3)*

The programs designed to achieve these objectives included freight distributor recognition schemes, improved truck driver education programs, development of delivery and service plans that reduce the number of truck deliveries, and the development of similar plans aimed at construction truck traffic.

As noted above, freight transportation affects and is affected by a wide range of environmental factors. Each impact has its own analysis methodology (often required by regulation or agency guidance), and each often results in very specific types of mitigation strategies. This chapter will examine some of the most important environmental impacts for the freight industry.

18.3.2 Sources and Impacts Characterized

Two variables are used in this chapter to categorize environmental events associated with freight transportation. The first variable represents a temporal context, capturing the event as either *episodic* or *routine*. Episodic events are acute in the environmental health sense and often imply a high impact over a short period of time. Typical policy actions to address episodic events involve safety and prevention measures (e.g., the use of disaster prevention protocols and/or best available control technologies). Episodic discharge events may be permitted under limited conditions or conceivably prohibited (except by accidental incident). Routine events represent impacts that occur as a normal result of goods movement. Routine events may be acute (emissions affecting air quality during peak concentration periods), but are often chronic and cumulative (e.g., bioinvasion from ship ballast water). Policy mechanisms aimed at addressing routine events involve emissions standards, technology mandates, and market-based incentives to modify operations. Regulation of routine releases has lagged policy action to address episodic discharges, partly because these impacts were not as well understood in the past, and partly because operational behavior must change or new technology is required.

The second variable has to do with whether such events are *source-specific* (i.e., attributable to the freight mode alone) or whether they are a *systemic* aspect of the freight network (i.e., freight modes interacting with other components in the system, including system infrastructure). Source-specific implies that policy mechanisms aimed directly at vehicles or modes may be most successful in reducing impacts from such events; systemic implies that integrated policies aimed at larger market behavior would be most effective, which may involve working with a variety of stakeholders in order to achieve policy goals. These designations help to explain why some aspects of freight transportation, such as air emissions or greenhouse gases, are so challenging to address. Example environmental events under this taxonomy are listed in Table 18-1. This list is not exhaustive and does not fully address related issues included in some environmental impact statement (EIS) contexts or land use research that may not be directly tied to the freight network.

Table 18-2 identifies general policy instruments that have been effective in addressing different parts of this event matrix. Freight policy actions are initiated at local, regional, national, or international levels. A local example is the Green Port Policy of Los Angeles and Long Beach that demonstrates how a port can mitigate freight-related environmental impacts. National level efforts include EPA action, while regional efforts include both subnational (e.g., California) policy and supranational (e.g., European Union) policy

Table 18-1 Types of environmental events due to freight transportation

	Episodic (Acute) Environmental Events	Routine (Chronic) Environmental Events
Vessel		
Source-specific	Ship-strikes with marine life Oil spills Ocean dumping Sewage discharges Incineration emissions Oily wastewater	Engine air emissions Hull coating toxic releases Cargo evaporative losses Dust (mostly from dry bulk) Refrigerant "fugitive" emissions Underwater noise
Systemic	Vessel grounding and/or collisions Dredging Port expansion impacts (various) Ship construction, breaking	Invasive species introductions Port stormwater runoff Vessel wake erosion
Truck		
Source-specific	Spills and leaks	Engine air emissions Cargo evaporative losses Dust (mostly from dry bulk) Noise Refrigerant "fugitive" emissions
Systemic	Maintenance discharges Collisions with other traffic	Stormwater runoff Road and tire dust
Rail		
Source-specific	Spills and leaks	Engine air emissions Cargo evaporative losses Dust (mostly from dry bulk) Noise Refrigerant "fugitive" emissions
Systemic	Maintenance discharges Derailments or grade crossing collisions	Stormwater runoff Road and tire dust
Aircraft		
Source-specific	Spills and leaks	Landing and take-off air emissions Contrails Aircraft Noise
Systemic	Maintenance discharges	Ground equipment emissions Stormwater runoff Road and tire dust
Facilities and Crosscutting		
Source-specific	Brightness and glare from lights	Noise
Systemic	Worker exposure Solid waste generation	Community welfare Land use

frameworks. International policy actions typically address international aircraft or shipping, or represent larger multinational treaty frameworks. This chapter does not evaluate or compare the various histories of regulatory action at each of these jurisdictional or geospatial scales.

18.3.3 Health Consequences of Environmental Impacts

The consequences to public health of environmental effects are ultimately some of the most important considerations in environmental analysis and policy development. For example, national ambient air quality standards and threshold values for specific air and water pollutants are directly related to when a set level of pollutant concentration starts to affect human health (as as well as ecological function). With respect to freight, particulate matter (PM) as part of air pollutant emissions poses special concerns. Freight transportation is responsible for 50% of directly emitted PM from mobile sources (Figure 18-3). Studies indicate that, along with transportation workers, the public at greatest exposure risk include those who live and work near areas of high diesel activity, and people who spend significant periods of time commuting along major roads. Regulatory agencies, academics, and science-based health organizations are beginning to quantify the expected benefits of reducing PM emissions specifically from diesel sources.

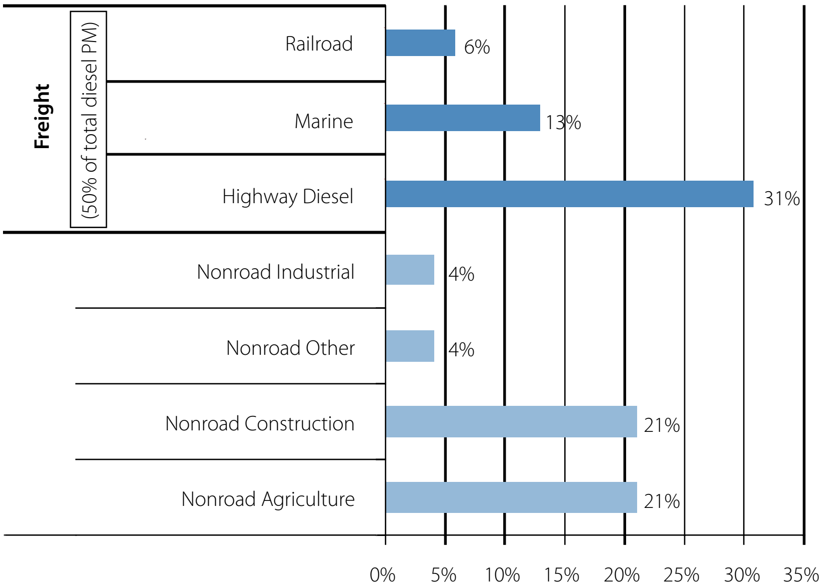
High concentrations of PM have been associated with a wide range of health impacts including asthma, heart attacks, and hospital admissions. An important PM-related health effect is premature mortality. Increases in concentrations of PM with aerodynamic diameters of 2.5 microns or less ($PM_{2.5}$) have been closely associated with increases in cardiopulmonary and lung cancer mortalities in exposed populations. *(4, 5)* Some researchers have estimated that outdoor $PM_{2.5}$ air pollution causes approximately 0.8 million deaths per year worldwide or 1.2% of annual global premature mortalities. *(6)*

With respect to transportation workers, the Health Effects Institute concluded that, "The available evidence suggests that long-term exposure to die-

Table 18-2 Policy mechanisms for addressing different types of environmental events (episodic/routine and source/system taxonomy)

	Episodic (Acute)	Routine (Chronic)
Source-specific	• Accident prevention measures • Disaster management planning • Inspection and maintenance requirements • Episodic event technology mandates (e.g., double-hull ships and leak protection)	• Emissions control standards • Technology-driven mandates • Technology-forcing mandates • Market-based incentives for reductions • Labeling and/or reporting requirements
Systemic	• System-wide safety management planning • Infrastructure inspection and maintenance • Emissions offset requirements for one-time events (e.g., port expansion)	• Multisource cap-and-trade programs • Multisource emissions netting or offsetting • Infrastructure inspection and maintenance

Figure 18-3 Percentage of directly emitted diesel PM in the United States (2004)



SOURCE: Cited reference *15*.

sel exhaust in a variety of occupational circumstances is associated with a 1.2- to 1.5-fold increase in the relative risk of lung cancer compared with workers classified as unexposed." *(7)* Recent literature relates health risk from diesel particulate matter (DPM) to time and proximity of exposure through implicit comparison among transportation workers and through explicit epidemiological research design.

Workers face additional health risks when exposed to DPM in closed spaces, such as in cabins or poorly ventilated spaces. *(8)* Occupational exposure at terminals and transportation facilities varies significantly with worker duties, background levels, weather conditions, proximity to other exposure sources, and geographic location. *(9)* Mariners live and work in close proximity to diesel emission sources. *(10, 11)* According to a study by Saarni et al., lung cancer incidence rates were higher for engine crew personnel compared with deck officers, suggesting that reduced exposure in open or ventilated locations on ships—generally forward of the engine exhaust and outside of machinery spaces—reduces the risk to similar worker cohorts on the ship. *(12)*

Rail workers exposed to diesel exhaust are also at increased risk of lung cancer compared with other populations, and relative risk varies with number of years of work. *(13)* In some studies, rail workers had a 40% higher risk of lung cancer compared with the general population, with even more elevated lung cancer mortality for those rail jobs involving diesel powered locomotives. *(14)* Again, proximity and duration of exposure to DPM is closely associated with these health risks.

18.4 Air Quality

Statistics for the United States show that freight transportation contributes a significant share of the nation's air pollutant emissions inventory. *(15)* Four major freight transport modes are usually included in such analyses—truck, rail, ship, and air. (Because this chapter is aimed at the major vehicle modes and intermodal transportation, pipelines are not addressed here.) Table 18-3 shows the overall contribution of these different freight modes to nitrogen oxide (an important component in the production of ozone) and particulate matter. Importantly, freight transportation, and notably trucking, contributes almost half of the nation's nitrogen oxides from mobile sources and just over 25% for all sources. For particulate matter, freight transportation contributes just over one-third of all mobile source particulate emissions.

New regulations affecting emissions from trucks, ships, and locomotives aim to reduce the environmental impacts of freight transportation in the future, particularly for emissions of sulfur oxides (SO_x), nitrogen oxides (NO_x), and PM. This is true internationally and in the United States. The total amount of NO_x and PM_{10} is expected to decline for both trucking and freight railroads, even with growth in total ton-miles carried, primarily because of the new pollutant emission standards. In contrast, air-freight-related emissions are expected to increase.

18.4.1 Heavy Duty Diesel Trucks

The changes in emission standards over time for heavy duty diesel trucks (HDDT) in the United States are shown in Table 18-4.[2] For NO_x and PM, these emission standards represent tailpipe emissions and are measured in grams per brake horsepower-hour (g/bhp-hr).[3] Sulfur oxide emissions are handled a bit differently, and the regulations are aimed at the sulfur content of fuel used in HDDTs (measured in parts per million [ppm]). The on-road standard of 500 ppm was recently changed to 15 ppm (known as ultra-low sulfur diesel fuel). This new fuel quality standard not only reduced sulfur emissions from trucks, but also allowed the installation of NO_x emission control technologies that allowed trucks to achieve new, lower NO_x standards (0.20 g/bhp-hr in 2007).[4] (See www.epa.gov/OMS/cert/hd-cert/stds-eng.pdf for the most up-to-date information on emission standards relating to heavy duty trucks.)

2 Emission standards discussed in this section are taken from the US Code of Federal Regulations, Volume 40, various sections.

3 To convert these values to g/kWh multiply by 1.341.

4 Sulfur is a well-known "poison" to many catalysts, and so the use of catalytic NO_x emissions control systems are infeasible when fuel sulfur levels are high.

Table 18-3 US freight transportation NO_x and PM_{10} emissions by mode, 2002

	NO_x Emissions				PM_{10} Emissions			
			As percent of:				As percent of:	
Mode	Tons	Percent	All Mobile Sources	All Sources	Tons	Percent	All Mobile Sources	All Sources
Heavy duty vehicles	3,782,000	66.8	33.0	17.9	120,000	64.7	23.3	0.5
Freight railroads	857,200	15.1	7.5	4.1	21,300	11.5	4.1	0.1
Marine vessels	1,011,000	17.9	8.8	4.8	44,000	23.7	8.5	0.2
Air freight	8,200	0.1	0.1	0.0	300	0.2	0.1	0.0
Total	5,658,400	100	49.4	26.8	185,600	100	36.0	0.8

SOURCE: US EPA, National Emission Inventory; total mobile source emissions and total emissions obtained from state air quality agencies. Freight railroad emissions estimated as 96.4% of total railroad NO_x emissions and 96.7% of total railroad PM_{10} emissions, based on passenger locomotive fraction in US EPA, *Locomotive Emissions Standards, Regulatory Support Document,* April 1998. Air freight emissions estimated as 10.1% of total aircraft emissions, based on air estimated aircraft departures attributable to air freight, as described in report text. www.fhwa.dot.gov/environment/freightaq/chapter2.htm.

Table 18-4 Emission standards for heavy duty diesel trucks in the United States (1996–2008)

Year	NO_x (g/bhp-hr)	PM (g/bhp-hr)	Sulfur (ppm)
1996	5.0	0.10	500
1997	5.0	0.10	500
1998	4.0	0.10	500
1999	4.0	0.10	500
2000	4.0	0.10	500
2001	4.0	0.10	500
2002	4.0	0.10	500
2003	4.0	0.10	500
2004	2.4†	0.01	500
2005	2.4†	0.01	500
2006	2.4†	0.01	15
2007	0.20	0.01	15
>2008	0.20	0.01	15

†This value applies to NO_x + NMHC (non-methane hydrocarbon) emissions.

18.4.2 Rail Locomotives

Emissions from rail locomotives were unrestricted until the 1990 Clean Air Act Amendments instructed the EPA to establish emission standards for locomotives and other traditionally nonregulated mobile sources. The regulations for locomotives are more complicated than for HDDTs, as different standards apply to different locomotive uses (line-haul versus switch operation cycles) and different sizes. In March 2008, EPA issued new regulations concerning locomotive and marine engine emissions. As noted in the justification for the new regulations, estimates showed that, without the emission reductions from the action, by 2030 locomotive and marine diesel engines would contribute more than 65% of national mobile source diesel $PM_{2.5}$, or fine particulate, emissions and 35% of national mobile source NO_x emissions, a key precursor to ozone and secondary PM formation. With some limited exceptions, the regulations apply to all diesel line-haul, passenger, and switch locomotives that operate extensively within the United States, including newly manufactured locomotives and remanufactured locomotives that were originally manufactured after 1972.

These regulations represented important changes from the previous standards. First, the final standards for existing locomotives and marine diesel engines are more stringent when they are remanufactured. These standards take effect as soon as certified remanufacture systems are available. Second, the rule sets near-term emission standards, referred to as Tier 3 standards, for newly built locomotive and diesel marine engines. These standards reflect the application of currently available technologies to reduce engine-out PM and NO_x emissions, and the phase-in started in 2009. The rule also creates new idle reduction requirements for new and remanufactured locomotives and establishes a new generation of clean switch locomotives, based on clean nonroad diesel engine standards. Third, the final long-term emissions standards, referred to as Tier 4, apply to newly built locomotives and marine diesel engines. These standards are based on the application of high-efficiency catalytic aftertreatment technology and will phase-in for marine diesel engines beginning in 2014 and for locomotives in 2015. These standards are enabled by the availability of ultra-low sulfur diesel fuel with sulfur content capped at 15 parts per million, which will be available by 2012. The marine Tier 4 engine standards apply only to commercial marine diesel engines above 600 kW (800 hp).

Tables 18-5 through Table 18-8 show the historic and current NO_x and PM emission standards for locomotives, based on whether they are line-haul or switch engines. Note that these standards apply to both new and remanufactured engines, as specified in the tables. Similar to HDDTs, sulfur emissions are addressed through a fuel quality standard, which required the use of 500 ppm sulfur fuel in 2007, with a reduction to 15 ppm sulfur fuel beginning in 2012. (See www.epa.gov/OMS/cert/hd-cert/stds-eng.pdf for the most up-to-date information on emission standards relating to locomotives.)

Table 18-5 Historic and current NO_x emissions standards for locomotives (build dates ranging from 1973–2008)

NO_x Limit (g/bhp-hr)	Model Year or Build Date	Effective Date	Operation
9.5	1973–2001	1998	Line-Haul
7.4	2002–2004	↓	Line-Haul
5.5	2005–2008	↓	Line-Haul
14.0	1973–2001	↓	Switch
11.0	2002–2004	↓	Switch
8.1	2005–2008	↓	Switch

Table 18-6 Future NO_x emission standards for locomotives

NOx Limit (g/bhp-hr)	Model Year or Build Date	Effective Date	Source	Engine Type
8.0	1973–2001	2010	Line-Haul	Remanufactured, w/ SLIAC†
7.4	1973–2001	2010	Line-Haul	Remanufactured, w/o SLIAC†
7.4	2002–2004	2010	Line-Haul	Remanufactured
5.5	2005–2011	2013	Line-Haul	New and Remanufactured
5.5	2012–2014	2012	Line-Haul	New and Remanufactured
1.3	>2015	2015	Line-Haul	New and Remanufactured
11.8	1973–2001	2010	Switch	Remanufactured
11.0	2002–2004	2010	Switch	New and Remanufactured
8.1	2005–2010	2013	Switch	New and Remanufactured
8.1	2011	2013	Switch	New and Remanufactured
5.0	2012–2014	2011	Switch	New and Remanufactured
1.3	>2015	2015	Switch	New and Remanufactured

†SLIAC represents separate loop intake air cooling; different standards apply to locomotives with (w/) or without (w/o) these systems. Also, some of these regulations only apply to remanufactured engines, as noted in the table.

Table 18-7 Historic and current PM emission standards for locomotives (build dates ranging from 1973–2008)

PM Limit (g/bhp-hr)	Model Year or Build Date	Effective Date	Source
0.60 0.45 0.20	1973–2001 2002–2004 2005–2008	1998	Line-Haul
0.30 0.22 0.10	1973–2001 2002–2004 2005–2008	2005	Line-Haul
0.72 0.54 0.24	1973–2001 2002–2004 2005–2008	1998	Switch
0.36 0.27 0.12	1973–2001 2002–2004 2005–2008	2005	Switch

Table 18-8 Future PM emissions standards for locomotives

PM Limit (g/bhp-hr)	Model Year or Build Date	Effective Date	Source	Engine Type
0.22	1973–2001	2010	Line-Haul	Remanufactured w/ SLIAC
0.22	1973–2001	2010	Line-Haul	Remanufactured w/o SLIAC
0.22	2002–2004	2010	Line-Haul	Remanufactured
0.10	2005–2011	2013	Line-Haul	Remanufactured
0.10	2012–2014	2012	Line-Haul	
0.03	>2015	2015	Line-Haul	
0.26	1973–2004	2010	Switch	Remanufactured Tier 0
0.13	2005–2011	2013	Switch	Remanufactured Tier 2
0.10	2012–2014	2011	Switch	Tier 3
0.03	>2015	2015	Switch	Tier 4

†SLIAC represents separate loop intake air cooling; different standards apply to locomotives with (w/) or without (w/o) these systems. Some of these regulations only apply to remanufactured engines, as noted in the table.

18.4.3 Marine Vessels

Domestic shipping is regulated in the United States in a manner similar to locomotives. The NO_x and PM regulations for domestic shipping are applied based on the model year or build date for the engine, the engine size (in liters per cylinder), and the engine power (in kw). As mentioned in section 18.4.2, the EPA in March 2008 issued regulations establishing a new generation of engine emission standards for commercial marine diesel engines, as well as locomotives. Table 18-9 shows the NO_x total hydrocardon (THC) and PM emission standards for category 1 and category 2 ships, noting that the NO_x standard really applies to NO_x plus THC emissions, with some exceptions. Based on these standards, it is expected that PM and NO_x emissions will be reduced by 80–90% over the next decade. Sulfur emissions from domestic shipping are controlled through a fuel quality standard. For ships, sulfur content was to meet a 500 ppm sulfur standard by 2007, and a 15 ppm sulfur standard beginning in 2012.

For international shipping, new regulations precipitated by the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI will affect ships in significant ways. *(16, 17)* Annex VI, an international agreement signed by more than 50 countries as of March 31, 2009, and representing more than 80% of world fleet tonnage, sets emission standards for ships involved in international trade (see Tables 18-10 and 18-11). In particular, the most recent additions to these international regulations relate to engine emission controls for nitrogen and sulfur oxides and particulate matter. MARPOL Annex VI provides for designation of emission control areas (ECA), where the adoption of special mandatory measures for emissions from ships is required. In March 2009, the United States and Canada formally requested under Annex VI that the International Maritime Organization (IMO) designate specific portions of the coastal waters of the United States and Canada as an ECA. *(18)* If approved by the IMO, the new standards could go into effect by 2015 and lead to a 96% reduction in sulfur in marine fuels, as well as a cut in emissions of PM by 85% and NO_x by 80%. (See www.epa.gov/oms/oceanvessels.htm and www.imo.org for more information.)

18.4.4 Greenhouse Gas (GHG) Emissions

To many, climate change is one of the most important environmental challenges facing society over the long term. One of the major contributors to climate change is the continued release of greenhouse gases (primarily carbon dioxide) into the atmosphere. The transportation sector contributes approximately 33% of the annual carbon dioxide emissions in the United States, with freight transportation contributing about 470 million metric tons of CO_2, or about 8% of total greenhouse gas emissions. *(19)* Of this, about 70% is from trucking. The

Table 18-9 NO_x, THC, and PM emission standards for Category 1 and 2 marine diesel engines

NO_x + THC (g/bhp-hr)	PM (g/bhp-hr)	MY or Build Date	Effective Date	Engine Size (Liters/cylinder)	Engine Power (kW)
5.6	0.30	2005	2000	<0.9	>37
5.4	0.22	2004		0.9–1.2	All
5.4	0.15	2004		1.2–2.5	All
5.4	0.15	2007		2.5–5.0	All
5.8	0.20	2007		5.0–15.0	All
6.5	0.37	2007		15.0–20.0	<3300
7.3	0.37	2007		15.0–20.0	>3300
7.3	0.37	2007		20.0–25.0	All
8.2	0.37	2007		25–30	All
5.6	0.30	2009	2008	<0.9	<19
5.6	0.22	2009			19–75
3.5	0.22	2014			
4.3[a]	0.15	2014			
4.0	0.10	2012			75 – <2000c
4.0	0.09	2013		0.9 – < 1.2	
4.2	0.08	2014		1.2 – <2.5	
4.2	0.08	2013		2.5 – <3.5	
4.3	0.08	2012		3.5 – <7.0	
4.3	0.30	2012	2008	<0.9	75 – <3700
4.3	0.22	2013		0.9 – <1.2	
4.3	0.22	2014		1.2 – <2.5	
4.3	0.15	2013		2.5 – <3.5	
4.3	0.11	2012		3.5 – <7.0	
4.6	0.10	2013		7 – <15	<3700
5.2	0.09	2014		15 – <20	
7.3	0.09	2014		20 – <25	
8.2	0.08	2014		25 – <30	
1.3[b]	0.10	>2017	2008	N/A	600 – <1400
1.3[b]	0.20	>2016			1400 – <2000
1.3[b]	0.20	>2014			2000 – <3700
1.3[b]	0.20	>2014			> 3700

a This is an optional emissions standard for NO_x + THC, so long as PM emissions are less than 0.15 g/bhp-hr.
b These values apply to NO_x emissions only. Other values in table apply to both NO_x and total hydrocarbon (THC) emissions.
c This value extends to 3700 kw for PM standards.

Table 18-10 NOx emissions standards for international shipping

Maximum Engine Speed	NO_x Limit (g/kWh) Tier I Engines	Tier II Engines	Tier III Engines (ECAs only)
RPM (Revolutions per Minute)	Installed 2000–2010	Installed 2011–2015	Installed 2016–
n < 130	17.0	14.4	3.4
130 ≤ n < 2000	$45.n^{(-0.2)}$	$44.n^{(-0.23)}$	$9.n^{(-0.2)}$
n ≥ 2000	9.8	7.7	2.0

Table 18-11 Sulfur content of fuel—limits in international shipping

Sulfur Content of Fuel (ppm) Non-ECA†	ECA	Effective Date
45000	15000	2005
		2006
		2007
		2008
		2009
	10000	2010
		2011
35000	10000	2012
		2013
		2014
	1000	2015
		2016
		2017
		2018
		2019
5000	1000	2020

† ECA is an "emissions control area."

disproportionate contributions of trucking and air to the total emissions picture is demonstrated by looking at the energy and carbon intensities associated with these modes of transportation. These are shown in Figures 18-4 to 18-6. Not directly addressed in this chapter is the emerging environmental and climate attention to particulate/aerosols such as black carbon that behave as short-lived climate forcers. Diesel engines are considered by some scholars and policy analysts to be an important source and possible non-GHG candidate for early action to mitigate climate warming potential while achieving health and environmental benefits.

International shipping is an important source of greenhouse gas emissions, and its contributions are sometimes counted separately from national emission inventories. As a sector outside of national summaries, global shipping CO_2 emissions are almost one gigaton/year and would rank sixth in the world if compared across national inventories—representing nearly twice Germany's CO_2 emissions and about 19% of annual CO_2 emissions from the United States. *(20)* Currently, the International Maritime Organization is updating its 2000 study of greenhouse gases from ships to evaluate the global trends and impacts of increased trade and energy use by intercontinental shipping, most of which is dedicated to freight transportation. *(21)*

18.4.5 Opportunities for Reducing Emissions

A number of strategies can be employed to reduce energy consumption and air emissions from freight activities. In this section, these strategies are categorized as follows:

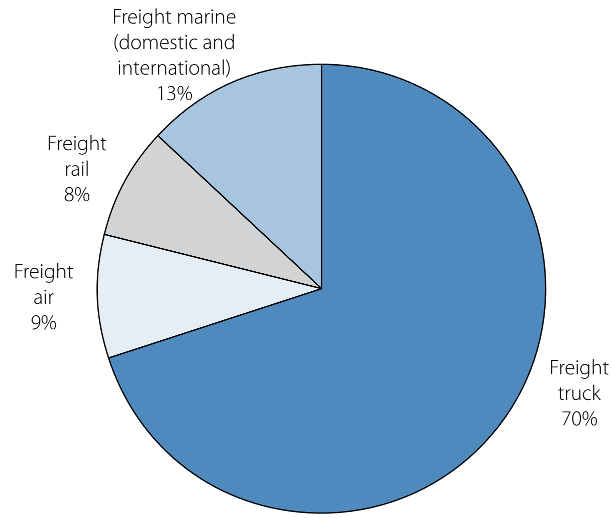
- Technology-based strategies (e.g., more efficient engines, improved hull/vehicle design, emissions control technology)
- Fuel-based strategies (e.g., low-sulfur fuels, low carbon fuels)
- Operations-based strategies (e.g., reduced speeds, reduced idling, time-of-day operation constraints)
- Logistics-based strategies (e.g., mode selection)
- Infrastructure-based strategies (e.g., improved infrastructure to allow more efficient operations/logistics)
- Demand management-based strategies (e.g., reduced overall ton-miles of goods movement)

The following mode-specific list identifies specific emissions and energy reduction strategies associated with different modes of transportation (*21, 22, 23, 24, 25, 26*):

Truck
- Use of alternative fuels and hybrids (discussed in the main body of this paper)
- Limiting truck speed
- Improved maintenance
- Compact land use planning
- Pooling urban delivery systems
- Use of trailer trains
- Use of hydraulic hybrids
- Improve aerodynamic drag reduction
- Reduce rolling resistance
- Reduce accessory loads through electrification
- Reduce idle (overnight and operational)
- Reduce empty mileage

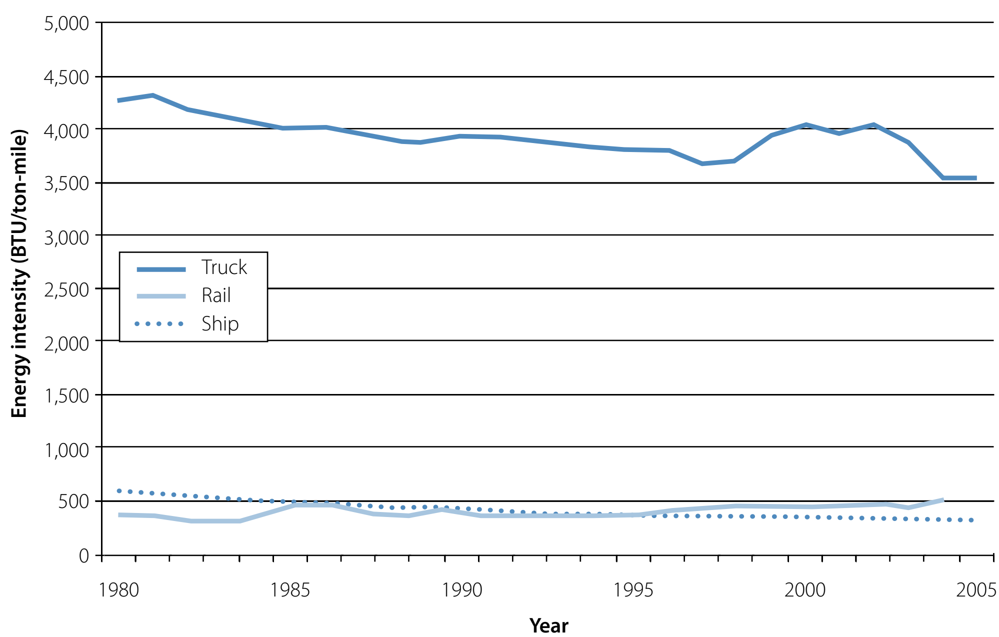
Rail
- Increased electrification
- Use of short-haul and long-haul rail instead of truck
- New, advanced, high-efficiency locomotive engines
- Hybrids for switch engines and/or locomotives (see discussion above)
- Monitoring systems to improve maintenance
- Logistics improvements
- Reduced idling
- Lightweighting railcars
- Regenerative braking
- Reduced aerodynamic drag
- Improve track lubricants
- Reduce line-haul speeds

Figure 18-4 Greenhouse gas emissions by modes in the United States, 2005



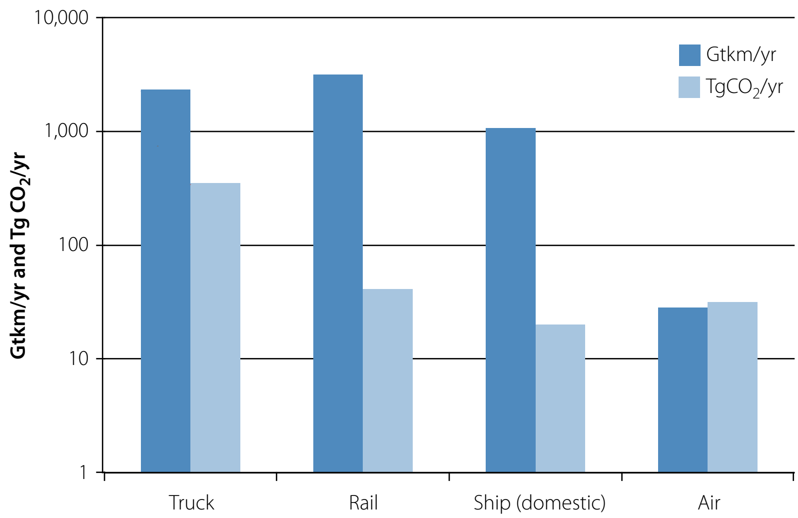
SOURCE: Derived from cited reference *19*.

Figure 18-5 Energy intensity of US freight modes (1980–2005), by type



SOURCE: Derived from cited references *5* and *19*.

➤ **Figure 18-6** Comparison of demand and CO_2 emissions by freight mode share in the United States, 2005



SOURCE: Derived from cited references *5* and *19*.

Shipping

- Shore power management and electrification
- Improve terminal operations to reduce queues and delays
- Use of barges and short sea shipping to replace trucks
- Improve vessel load/discharge operations
- Use of alternative fuels and distillates (see discussion above)
- Use of hydraulic hybrids
- Improved hull design and optimization
- Hull maintenance/cleaning
- High efficiency propulsion technology
- Speed reduction
- Improved routing and logistics (e.g., just-in-time routing and weather routing)
- Increase vessel size (mostly for large international container traffic)
- Reduce port equipment idling
- Electrification of cranes
- Port automation

Air

- Reduce aerodynamic drag
- Reduce plane weight
- Increase engine efficiency
- Improve ground support operations and equipment
- Improve air traffic control management

All Modes

- Emphasis on local production and consumption
- Modal shifts from truck to rail and ship (trucks consume about ten times more energy per work done than rail or shipping; therefore one could expect that for every 10% of freight that is moved from truck to rail/ship, greenhouse gas emissions from moving such freight is reduced by about 9%).
- Extend terminal gate hours in order to reduce idling time for trucks

Table 18-12 shows the results of a recent assessment of best practices in freight transportation for reducing greenhouse gas emissions and energy consumption. *(22)* According to this study, the best practices vary regarding their cost-effectiveness and payback periods. The most cost-effective best practices are plug-in units for the rail mode, direct-fired heater for the truck mode, and combined diesel powered heating system and auto engine start/stop system for the rail mode. The least cost-effective best practices are B20 biodiesel (i.e. 20% biodiesel) for the truck, rail, and water modes. Five best practices have payback periods of less than one year.

18.5 Water Quality

Many freight movements occur on inland water systems, along coastal channels, in ports, or at sites that have adjacent wetlands. Thus, the effect on water quality through the discharge of wastes or other contaminants into the natural water system can be a significant environmental issue. As noted in a report by the Organization for Economic Cooperation and Development, the water pollution issue focuses on many different issues.

> The routine discharge of ballast water from marine vessels, if ballast is not segregated from cargo, introduces oil pollution at sea and in coastal waters, and can lead to introduction of nuisance species transported from the boat's origin to its destination. Shipping is a source of oil and chemical spills at port, in coastal waters, and more rarely at sea. The routine maintenance dredging of ports and inland waterways stirs up toxic sediment and frequently leads to the disposal of dredged material in the open ocean. . . . Road accidents and vehicle exhaust are both sources of oil and hazardous chemicals which run off the road into surface and ground water. The roads themselves, as well as parking lots, driveways, and other paved surfaces lead to an increase in impermeable surfaces, particularly in urban areas. Impermeable surfaces interrupt the filtration of rainfall into the ground water. An increase in impermeable surfaces will therefore aggravate flood risk and lead to more pollutant runoff into surface waters in heavy rains. *(27)*

International and national water pollution laws and regulations establish standards and processes that must be followed in water transportation. For example, the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) put in place a set of discharge standards and equipment requirements designed to prevent operational oil pollution. *(16, 17)*

Table 18-12 Summary of potential greenhouse gas emissions reductions, energy use reduction, net savings, unit net savings, and simple payback periods of selected best practices[a]

Mode	Practice Name	Modal Greenhouse Gas Emission Reduction (10^6 ton CO_2 eq.)	Modal Energy Use Reduction (10^{12} BTU)	Net Saving ($\$10^6$)	Net Saving per Unit of Greenhouse Gas Emission Reduction ($/ton CO_2 eq.)	Net Saving per Unit of Energy Use Reduction ($/$10^6$ BTU)	Simple Payback period (year)
Truck	Off-Board Truck Stop Electrification	2.4	27	330	138	12	N/A[c]
	Auxiliary Power Units	15	185	440	29	2.3	3.2
	Direct Fire Heaters	7.6	94	1350	178	14	0.6
	Hybrid Trucks	24.5	300	3190	130	11	2.1
	B20 Biodiesel for Trucks	30.8	–370	–3300	-108	N/A[b]	N/A[d]
Rail	Combined Diesel Powered Heating System and Auto Engine Start/Stop System	2.3	29	390	167	14	2.1
	Battery Diesel Hybrid Switching Locomotive	1.1	14	70	65	5.2	5.5
	Plug-In Unit	0.4	4	135	364	38	0.8
	B20 Biodiesel for Locomotives	3.5	–42	–380	–109	N/A[b]	N/A[d]
Water	B20 Biodiesel for Ships	1.5	–18	–180	–120	N/A[b]	N/A[d]
Pipeline	Convert Natural Gas Pneumatic Controls to Instrument Air	0.7	1	12	18	9.6	0.3
	Replace High-Bleed Natural Gas Pneumatic Devices with Low-Bleed Pneumatic Devices	0.8	2	13	18	8.8	0.9
	"Hot Tap" Method	2.5	5	40	16	7.8	0.2

a These assessments are based on the assumptions that these best practices reach their potential maximum market shares in 2025 *(22)*.
b This practice has no energy use reduction due to an increase in energy use, and it has no net saving due to high annualized cost and no energy cost saving.
c There is no payback period for this practice because there is no initial capital cost to users.
d There is no payback period for this practice because there is no net saving.

The US Congress passed the Water Pollution Control Act in 1972 to restore and maintain the quality of the US waterway system. In 1987, the Water Quality Act amended the 1972 act to allow EPA to govern stormwater discharges from industrial activities, many of which are related directly to the level of impermeable surfaces associated with such activities. Intermodal freight facilities are subject to the permitting processes for stormwater management. Many other laws and regulations, too numerous to discuss here, are found in references to international, national, and state environmental legislation. (See, for example, the Environmental Standards Division of the US Coast Guard for information on water-related quality standards, www.uscg.mil/hq/cg5/cg522/cg5224/default.asp.)

The Port of Los Angeles's water quality strategy is a good example of the types of programs that might be considered as part of a comprehensive consideration of water resources for ports. The strategy includes the following elements. *(28)*

- *Water Resources Action Plan:* The ports of Los Angeles and Long Beach are cooperating on an action plan to protect water and sediment quality in the harbors. Both ports will integrate their existing programs and adopt new approaches especially those that exceed regulatory requirements.
- *Clean Water Program:* The Port has invested in water circulation/quality models and studies to determine how to improve water quality at nearby beaches. Storm drains and sewer lines have been repaired, and a proactive beach management strategy has been implemented.
- *Consolidated Slip Remediation:* The Port is working with the local water quality board to cleanup a toxic hotspot in the harbor. Remediation may include capping sediment or the removal of sediment to a confined site.
- *Oil Spill Prevention:* The Port participates in a state reduction program and helps manage a shared rapid response network/program.
- *Sediment Quality Improvement Programs:* For many years, the Port has remediated contaminated areas by sequestering the contaminants in confined disposal facilities or removing them to a special upland disposal area.
- *Watershed and Stormwater Management:* The Port has conducted a water quality modeling study focusing on storm water contamination from the major storm water channel feeding into the harbor. It is the first port on the west coast to implement a storm water treatment system at a container terminal.
- *Water Quality Monitoring:* The Port has monitored water quality at 31 stations in the harbor since 1967. Samples are tested on a monthly basis for dissolved oxygen, biological oxygen demand, and temperature.

18.6 Noise

Noise analysis is one the most developed areas of environmental impact analysis, having well-established methodologies. (*29, 30*) (See also www.fra.dot.gov/us/content/253.) The impact of noise on human interaction and human health is well documented. The degree of noise impact on individuals and on sensitive receptors (locations or buildings where activities could be particularly affected by loud noises, such as hospitals or schools) relates to loudness, sound duration, time of occurrence, and changes in noise levels with time. *(30)*

The unit of measurement is the decibel (dB). Given that the human ear can discern only a limited range of frequencies, an A-weighted sound level or "dBA" is most often used as the descriptor of community noise levels. As shown in Table 18-13, this measure acts as a threshold value for different levels of noise that, if exceeded, should be mitigated. Levels of between 50 and 70 dBAs usually represent normal daily activities; anything above 70 dBA would be considered noisy (note that the dBA scale is logarithmic, which means that an increase of 1 dBA represents a doubling of sound pressure). It is also important to note that noise varies with distance—the farther away a noise source is, the less sound pressure will be felt by the ear. For moving sources of noise, such as a flow of traffic, the decrease is 4.5 dBA for each doubling of distance; for stationary sources, such as a train yard, the decrease is 6.0 dBA for a doubling of distance.

Table 18-13 Noise threshold criteria (roads)

Activity Category	L_{eq}/(dBA)	Description of Activity
A	57 outdoors	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose
B	67 outdoors	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries and hospitals
C	72 outdoors	Developed lands, properties, or activities not included in Categories A or B
D	None	Undeveloped lands
E	52 interior	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums

SOURCE: Federal Highway Administration, *Highway Traffic Noise Analysis and Abatement Policy and Guidance,* 1995, www.fhwa.dot.gov/environment/polguid.pdf
L_{eq} – equivalent steady-state sound level

Given that noise levels will fluctuate over time (e.g., changing levels of traffic or plane arrivals), analysts calculate an equivalent sound level L_{eq}, which represents a sound level as if it was a steady, unchanging sound. L_{eq} is also estimated based on given time periods, thus for example, $L_{eq(24)}$ is the equivalent sound level over 24 hours. Similarly, statistical sound level descriptors L_{10}, L_{50}, L_{90} are used to indicate noise levels that have been exceeded 10, 50, and 90% of the time, respectively. A cumulative 24-hour exposure is called the day-night sound level, and is denoted as L_{dn}. This measure accounts for the fluctuations in A-weighted noise levels due to all sound sources during 24 hours.

For analysis purposes, rail generated noise analysis most often uses the maximum one-hour equivalent sound level ($L_{eq(1)}$) or the day-night sound level (L_{dn}), depending on land use category. For vehicular traffic, $L_{eq(1)}$ is used to determine potential impacts. The analysis process for estimating noise impacts of both rail and truck activities has been described in great detail by the Federal Highway Administration. *(31, 32)* In general, the approach begins with identifying potential noise-sensitive land use or receivers within impact noise boundaries (e.g., a distance of 750 unobstructed feet from a rail line is considered a potential impact area). A land use assessment is conducted and sensitive receptors are identified within the impact boundary. Assuming that such receptors exist, a detailed noise analysis is conducted that estimates the dBA levels that will be experienced at these receptors, and potential mitigation strategies are identified. Table 18-14 shows the types of mitigation strategies that might be considered as part of a noise study for rail operations.

18.7 Bringing It All Together: The Environmental Assessment Process

The previous sections have presented information on very specific environmental impacts that are of interest in freight-related project analyses. In reality, these potential impacts are often just one part of a much broader environmental analysis of potential environmental consequences of investment actions. Most national and state governments, international lending institutions, and even local planning ordinances have adopted formal processes that must be followed in conducting an environmental analysis of a project proposal. It is beyond the scope of this chapter to cover in great detail the characteristics and steps associated with freight-related environmental analysis. *(31)* However, some of the general guidelines that have been established by the US Council on Environmental Quality (CEQ) provide a good point of departure for understanding much of what is found in environmental analysis best practice. As noted by CEQ, environmental impact analysis includes the following at its most basic level:

- Assessment of the social, economic, and environmental impacts of a proposed action or project;
- Analysis of a range of reasonable alternatives to the proposed project, based on the applicant's defined purpose and need for the project;

Table 18-14 Noise mitigation measures and effectiveness

Application	Mitigation Measure		Effectiveness
Source	Stringent Vehicle and Equipment Noise Specifications		Varies
	Operation Restrictions		Varies
	Resilient or Damped Wheels*	For Rolling Noise on Tangent Track:	2 dB
		For Wheel Squeal on Curved Track:	10-20 dB
	Vehicle Skirts*		6-10 dB
	Undercar Absorption*		5 dB
	Spin-Slide Control (prevents flats)*		**
	Wheel Truing (eliminates wheel flats)*		**
	Rail Grinding (eliminates corrugations)*		**
	Turn Radii Greater than 1000 ft*		(Avoids Squeal)
	Rail Lubrication on Sharp Curves*		(Reduces Squeal)
	Movable-Point Frogs (reduce rail gaps at crossovers)*		(Reduces Impact Noise)
	Engine Compartment Treatments (Buses)		6-10 dB
Path	Sound Barriers Close to Vehicles		6-15 dB
	Sound Barriers at Right-of-Way Line		3-10 dB
	Alteration of Horizontal and Vertical Alignments		Varies
	Acquisition of Buffer Zones		Varies
	Ballast on At-Grade Guideway*		3 dB
	Ballast on Aerial Guideway*		5 dB
	Resilient Track Support on Aerial Guideway		Varies
Receiver	Acquisition of Property Rights for Construction of Sound Barriers		5-10 dB
	Building Noise Insulation		5-20 dB

* Applies to rail projects only
** These mitigation measures work to maintain a rail system in its as-new condition. Without incorporating them in the system, noise levels could increase by up to 10 dB.

- Consideration of appropriate impact mitigation: avoidance, minimization and compensation;
- Interagency participation, coordination, and consultation;
- Public involvement including opportunities to participate and comment; and
- Documentation and disclosure.

Analyzing alternatives is considered to be the most important activity in an environmental impact analysis. The CEQ requires agencies to:

- Rigorously explore and objectively evaluate all reasonable alternatives and, for alternatives that were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.
- Devote substantial treatment to each alternative considered in detail, including the proposed action, so that reviewers may evaluate their comparative merits.

- Include reasonable alternatives not within the jurisdiction of the lead agency.
- Include the alternative of no action.
- Identify the agency's preferred alternative or alternatives, if one or more exists, in the draft statement and identify such alternative in the final statement unless another law prohibits the expression of such a preference.
- Include appropriate mitigation measures not already included in the proposed action or alternatives.

The significance of an environmental impact is a function of both an alternative's *context* and *intensity*. Impacts could be analyzed from the point of view of several contexts: national, regional, local, affected interests, etc. Significance varies with the setting of the proposed action. For example, something that might be considered significant at a local level might not reach such a level when viewed from a regional perspective. Intensity refers to the severity of impact. The CEQ recommends the following be considered in evaluating intensity:

- Impacts that may be both beneficial and adverse. A significant effect may exist even if the federal agency believes that, on balance, the effect will be beneficial.
- The degree to which the proposed action affects public health or safety.
- Unique characteristics of the geographic area, such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
- The degree to which the effects on the quality of the human environment are likely to be highly controversial.
- The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
- The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
- Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
- The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.

- The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
- Whether the action threatens a violation of federal, state, or local law or requirements imposed for the protection of the environment.

Many observers of a typical environmental process have suggested that the process is too cumbersome and often subject to delays due to controversies on particular topics. A 2001 study by the Federal Highway Administration of several intermodal freight projects (involving public funding) concluded the following:

- Intermodal freight transportation projects, depending on federal funds or permits, frequently involve a variety of federal agencies as reviewers or that could be directly affected (port improvements and landside access issues).
- Clear communications and early involvement of federal and state agencies was critical to the successful completion of environmental analysis for the projects (time, money spent, design of project, etc.)
- Conflicts between state and federal environmental requirements can cause delays on projects but can be overcome with early recognition of issues and agreements among agencies on how to proceed.
- The variety of environmental issues that can become a concern on a given project depend on the nature of the project and the location of the project. They are not uniform for every project.
- Consideration of environmental resources (including avoidance and minimization of impacts through site selection and design) early in the planning and project design phases can result in simplified environmental review and avoidance of costly delays in project schedules.
- Early coordination with public interests on intermodal freight projects can lead to resolving concerns before they become a problem.
- NEPA streamlining through improved agency consultation may be difficult to achieve on many projects if the regulatory agencies do not have adequate resources to engage in early consultation.
- When questions or disagreements arise over the assumptions behind a project's purpose and need, and alternatives, regulatory agencies do not always have the resources to independently verify cargo projections, market analyses, and facility land use needs. They have to rely on the lead agency to comply with the NEPA requirement for independent verification of the information and analyses submitted by a permit or funding applicant.

- Port dredging, land-side development, and land-side access projects are sometimes covered by separate NEPA documents because funding is not always available to cover all three types of activity simultaneously and because different agencies take the lead on these projects. *(32)*

18.8 Environmental Management Systems and Other Environmental Stewardship Programs

One of the ways that freight companies can establish and monitor their actions with respect to environmental impacts is through the development and use of an environmental management system (EMS). An EMS can be developed in response to internal pressures for improving environmentally related corporate actions, or it can be developed in order to satisfy certification requirements (for example, to be certified by the International Organization for Standards—ISO). The American Association of State Highway and Transportation Officials (AASHTO) defines an EMS as follows:

> An EMS is the organizational structure and associated responsibilities and processes, procedures, and tools for integrating environmental considerations and objectives into the ongoing management decision-making processes and operations of an organization. *(33)*

AASHTO also notes that the environmental benefits associated with an EMS in transportation agencies include

- Reductions in the number, type, and severity of compliance incidents;
- Pollution and waste quantity reductions;
- Recovered resources; and
- Streamlined permit and document reviews and approvals.

Business performance improvements include:

- Reduced regulatory oversight schedule and cost burdens,
- Faster project delivery and, in turn, labor savings through streamlined reviews and approvals,
- Improved relationships with external stakeholders,
- Increased workforce efficiency, and
- Cost savings and cost avoidances from the integration of environmental needs and opportunities into both long-range and day-to-day activities.

One of the common ways of having a certified environmental management system is to apply to ISO and submit evidence that a company's EMS satisfies certification criteria. In particular, the ISO 14001 standard applies to an EMS and requires the following:

- A policy statement which includes commitments to prevention of pollution, continual improvement of the EMS leading to improvements in overall environmental performance, and compliance with all applicable statutory and regulatory requirements.
- Identification of all aspects of the community organization's activities, products, and services that could have a significant impact on the environment, including those that are not regulated.
- Setting performance objectives and targets for the management system which link back to the three commitments established in the community or organization's policy (i.e., prevention of pollution, continual improvement, and compliance).
- Implementing the EMS to meet these objectives. This includes activities like training of employees, establishing work instructions and practices, and establishing the actual metrics by which the objectives and targets will be measured.
- Establishing a program to periodically audit the operation of the EMS.
- Checking and taking corrective and preventive actions when deviations from the EMS occur, including periodically evaluating the organization's compliance with applicable regulatory requirements.
- Undertaking periodic reviews of the EMS by top management to ensure its continuing performance and making adjustments to it, as necessary. *(34)*

Even if a company does not implement an EMS program, there are other ways that it can participate in environmental stewardship programs. For example, in 2004, EPA initiated the SmartWay program, a brand that is associated with environmentally cleaner, more fuel efficient transportation actions. *(35)* EPA's SmartWay transportation programs result in significant, measurable air quality and/or greenhouse gas improvements while maintaining or improving current levels of other emissions or pollutants or both; an emissions calculator is provided to participants for estimating the savings likely to occur given certain actions.

An example of the types of actions that would qualify for membership in the SmartWay program comes from ABF, Inc., a major trucking firm. *(36)* Since 1976, ABF has voluntarily limited the maximum speed of its trucks, which reduces fuel consumption and emissions, partially offsets fuel economy degradation of the newer engines, and reduces the number and impact of crashes. Beginning in 1994, when the technology became available to prohibit discretionary engine idling, all new equipment purchases included computerized idle shutdown. ABF further reduces fuel consumption and enhances operational efficiency with practices that include a strict equipment maintenance schedule and an aggressive equipment replacement program (the average age of ABF road tractors is one and a half years). ABF has maintained a fuel efficiency/environmental performance score of 1.25—the highest score possible—since joining the SmartWay program in 2006.

18.9 Summary

The history of freight is an example of the interaction between economics, energy, and environment. Although in the past the economic dimension of freight movement drove its decision making, this is not true today. Present and future constraints on energy resources and concerns about the environment require that the future of freight will depend on a careful balance of all three aspects of freight movement.

Today, we move goods in support of an economy, but working within stricter environmental performance requirements. Cleaner freight transportation has depended upon putting the best technologies and fuels into fleets. Current regulatory standards have reduced criteria pollutants by more than 90% from uncontrolled levels, and they will eventually reduce power-weighted emissions by about 99%. However, technology improvements to reduce energy intensity cannot decouple the work-energy relationship and will not offset projected freight growth.

Logistics and operations changes have been suggested by the Intergovernmental Panel on Climate Change as promising ways for the freight sector to contribute to greater sustainability. In fact, the freight system is changing logistics practices in response to fuel price increases. The most dramatic short-run change is a lower velocity of freight transport. Ships are slowing down, less freight is moving by air, truck fleets are monitored for freeway speed, and some goods are shifting to rail.

Despite technological improvements and logistical solutions, infrastructure represents a barrier that limits short-term achievements. With renewed infrastructure, we can improve mode-transfer points, avoid crossing conflicts, and design agility into the freight system. Given that intermodal shipments must be packaged or reconsolidated for the weakest link in the supply chain—whether that is volume constraints through rail tunnels or road-weight limits—the future of freight must include critical infrastructure improvements.

Ultimately, freight growth requires more than a technology fix. We need to understand that in the early twenty-first century containerized and less-than-truckload (LTL) intermodal system, half of what was moved (prior to and following the recession in the latter part of the first decade) at a just-in-time pace was air: air around packaging, air space in containers, and LTL loads in tall vans that allow a single person to lift boxes at person height. Demand management—including the understanding and education of consumer expectations—

needs greater attention. With demand management innovation alongside new technology, operational advances, and renewed infrastructure, future freight movement should be able to accomplish its intended function, but in a way that is much more environmentally sound and sustainable than today.

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19

Labor and Human Resources

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19.1 Introduction

The transportation industry historically has been very labor intensive. For thousands of years people traded goods across continents and seas—either on foot, on pack animals, or over water. Surface freight transport was limited to pack horses initially, until larger wagons pulled by teams of horses became more common during the eighteenth and nineteenth centuries. Teamsters driving the eight-horse teams on Russell's Flying Waggons, for example, covered 100-120 miles per week, often on foot, typically working 60-70 hours per week. Their task was to ensure that each horse in the team pulled its share of the load, and work was fatiguing and dangerous. These one and a half ton wagons carried four to six tons of freight at an average speed of just under two miles per hour until they became obsolete when canals and railroads replaced them with faster overland transport options. (*1,* pp. 123–132) The speed and efficiency of railroads relegated horse-driven teams to drayage, cartage, and local delivery for the most part.

Longshoring, dock work, and warehousing were also labor-intensive industries. Before the development of mechanized loading and warehousing operations, this work required substantial crews of brawny laborers. Longshoring, in particular, required workers to climb into and out of the holds of ships, carrying heavy loads of goods one "pick" at a time. Warehousing required a similar degree of manual labor.

As transport technology changed, so did the demand for manual labor. Diesel engines did not require men to stoke coal furnaces. The development of the container in the late 1950s marked a major technological breakthrough for longshoring, moving the loading and unloading operations away from the ship

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and into more widely scattered labor markets, and reducing the number of workers needed to load ships and other freight conveyances. About the same time, piggyback trailers (trailer-on-flatcar, or TOFC) began to have a similar effect on the railroad boxcar business, allowing shippers to load trailers under their own control and seal them shut. (*2,* pp. 43–50) As with containers, piggybacks reduced duplicate handling costs and boosted the intermodal business; both these technologies combined to make the boxcar virtually obsolete. With bigger ships, trucks, and other freight vehicles, growing labor productivity has continued to reduce labor demand. The recent development of new labor-saving information technologies makes it possible to de-skill the work and ensure more reliable delivery of service. *(3)*

Despite massive changes, labor continues to be an essential part of freight transport. This chapter discusses labor and human resource issues in freight transport. From the labor perspective, transport historically has included both people and freight, so the development of the role and status of labor is embedded in transport generally. Section 19.2 traces the historical development of surface freight transportation, reviewing labor practices in rail, roadway, and maritime and inland waterway transport, with attention to the special problems facing longshore and warehouse work. Historical progress includes discussions in Sections 19.3 and 19.4 of the development of labor market institutions and labor standards as a result of worker self-organization, which was accomplished mainly through worker self-help or benevolent associations, labor unions, and legislation. Many of the most important labor regulatory institutions were developed by and for transportation workers. Section 19.5 addresses the impact of deregulation on the transport labor force and examines the protections that have been lost. Section 19.6 discusses current labor strategies and challenges.

19.2 History of Labor in the Freight Industry

The history of labor in the freight industry includes substantial conflicts over wages, working conditions, and the right to organize. This section provides an overview of labor in the major freight modes and discusses the development of unions and labor legislation. Labor conflict has a long history in transportation, particularly in freight transportation. Part of this may be due to the rough character of workers in this industry; history and literature abound with stories of brawling and carousing seamen, dock workers, and teamsters, including the involvement of organized crime. *(1, 4, 5, 6, 7)*

19.2.1 Railroads

The railroad may have been the most important technological innovation of the nineteenth century. Railroads made overland transport economical and played a critical role in industrial development; they were the high-tech industry of the era. Railroads allowed land development to occur outside of major sea and river ports, but the economic power they wielded became a tool of speculators and robber barons as well. Competition over railroad investments became the touchstone of economic development and the growing conflict with labor.

19.2.1.1 Railroad Strikes and Labor Unrest

The unregulated American economy expanded and contracted in great booms and busts throughout the nineteenth century, and the intensity of these booms and busts contributed to great labor conflict. The boom-and-bust cycle occurred because the monetary system and the laissez-faire approach to financing during that period led to land, mortgage, and other speculations; when speculators lost their fortunes, they often took the rest of the economy with them.[1] On July 14, 1877, in the midst a long bust that followed the financial panic of 1873, railroad workers walked off the job in Martinsburg, West Virginia, after a 10% wage cut. Their actions sparked a railroad strike that rolled across the nation from east to west. By the end of July, this strike wave had reached Chicago, where in addition to railroad workers, a large portion of the industrial workforce began a general strike sparked by the polarizing social tension that had been growing between the rich and poor throughout the century. The strike lasted 45 days and paralyzed the nation's railroads, its most critical transportation infrastructure. *(8, 9)*

A similar set of circumstances culminated in the greatest strike of the wave that had begun in 1877. Eugene V. Debs, the leading figure in the railroad brotherhoods, created the first American industrial union, the American Railway Union (ARU), to resolve the bitter conflicts that had plagued the railroad craft unions since their inception. The ARU successfully challenged repeated wage cuts ordered by James J. Hill's Great Northern Railroad in reaction to the depression created by the panic of 1893. An 18-day strike in April 1894 shut down the Great Northern, and in response, the railroad restored some of the wage cuts. *(10)*

On May 11, 1894, Pullman Palace Car Company workers declared a strike after George Pullman—the creator and manufacturer of the popular convertible sleeper cars—cut wages 23% in response to the depression. On June 26, the ARU agreed to honor the Pullman workers' picket lines and refused to handle Pullman Cars, causing the railroads to shut down and prompting federal action, including the appointment of a special attorney who obtained an injunc-

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1 For an accessible summary, see R. McNamara, *Financial Panics of the 19th Century.*

tion against the strike as a violation of the Sherman Anti-Trust Act.[2] The railroads employed strikebreakers to intimidate workers into crossing picket lines, and federal action ultimately included federal marshals and troops to suppress the strike. *(10)*

19.2.1.2 Rail Conflict and Federal Regulation

The railroad strikes of 1877 and subsequent strikes against the Gould Railway System (1886) and the Chicago, Burlington, and Quincy Railroad (1888) prompted Congress to use the Commerce Clause to pass the Arbitration Act of 1888, representing the first effort to regulate labor relations in railroads and in private-sector employment generally. Economic paralysis caused by railroad strikes made this legislation a practical necessity, and the act used arbitration and investigation as tools. President Grover Cleveland invoked the investigation mechanism in 1894 during the Pullman Strike, to no conclusive effect; this was the first such action taken by the US government.[3]

The Erdman Act of 1898, passed in response to the inadequacy of the investigation provision of the Arbitration Act, emphasized mediation and arbitration at the request of either labor or management. When the union requested mediation during 1898-99 and the railroads refused, Erdman lapsed into disuse for seven years, but between 1906 and 1913, 61 disputes were resolved within the provisions of the act, mostly by mediation. The Newlands Act of 1913 amended the Erdman Act and established a Board of Mediation and Conciliation to resolve labor disputes. In 1916, the railroad unions threatened a nationwide strike unless they were allowed an eight-hour workday with wage parity to the existing 10-hour day. The Adamson Act (1916) met their demands, and a strike was avoided.

During World War I, the federal government took over the railroads to prevent further conflict by creating a Railroad Administration that encouraged unionization and negotiated national contracts with the railroad brotherhoods, which were the first truly national, industry-wide labor agreements. (*11,* pp. 123–127)

The federal government takeover of the railroads ended upon the conclusion of the war. The unions preferred government control because they had received the institutional recognition they had sought for so long, but neither the railroads nor the Congress agreed. In the Transportation Act (1920), Congress further amended the growing body of law and created a US Railroad Labor Board to mediate and arbitrate disputes, but as the unions sought to maintain their gains and the companies sought to reverse them, the new law could not handle the growing conflict. Following the Shopmen's Strike of 1922 and the Supreme Court's subsequent refusal to enforce a decision of the Railway Labor Board to

2 The use of the Sherman Act against unions in this case foreshadowed later uses of the act to forbid unions' collective action both in bargaining and in strikes.

3 President Cleveland appointed the railroads' attorney as the special government attorney for Chicago, also over the governor's objection, and this may have contributed to the lack of effectiveness of arbitration and investigation.

invalidate a railroad's recognition of a company-dominated union, the law collapsed. Finally, based on a labor and management agreement on terms and conditions, Congress passed the Railway Labor Act (RLA) of 1926 (*11,* pp. 127–128), making the railroads the first industry to enter the modern era with industrial unionization (e.g., all workers in the same union). The RLA became the institutional foundation upon which the New Deal labor relations system rested.

19.2.2 Trucking and Its Antecedents

Trucking emerged from the horse-team era following the successful use of motorized vehicles in World War I. The mechanized personal vehicle had become widely used as a multipurpose vehicle, and during WWI people realized the usefulness—and flexibility—of the motorized truck to transport men and supplies. They could not haul heavy loads; rugged chain-drive Mack AB and AC model straight trucks, for example, hauled little more weight than did Russell's Flying Waggons nearly 100 years earlier, but the advantages of trucks became apparent.[4] One intercity freight carrier, Yellow Freight System, had its roots as a taxi company in Kansas City that expanded to become a trucking company simply by carrying freight along with passengers. *(12)*

19.2.2.1 Drayage, Cartage, and Local Delivery

As railroads grew throughout the nineteenth and early twentieth centuries, horse teams continued to pull carts and wagons in local delivery. Local delivery included the "crafts" of milk, soda, beer, bread, ice, and coal delivery, bringing these and other products directly to consumers. Frequently, the delivery process was commingled with the entrepreneurial aspect of sales, as drivers often bought and sold goods, as well as transported them.

Work typically was long and hard and paid poorly; teamsters (men who drove teams of horses pulling wagons) fed and groomed the horses for which they were responsible (whether or not they owned them), loaded and unloaded their own wagons, and typically worked 12–18 hour days at least six days per week with very few holidays. (*5,* pp. 18–19) Labor organizations for these workers generally had local origins and emerged often as trade associations representing team owners.

Strikes and labor conflicts between teamsters, teaming companies, and shippers were as decentralized as the industry, so the disputants wrapped them in local politics and often in various kinds of racketeering. It was possible for a labor leader who could control the actions of local teamsters to threaten and undertake boycotts that paralyzed freight delivery in a local area. Such actions characterized localized labor activity in major US cities, such as Boston, Chicago, and San Francisco. (*5, 13*)

4 www.macktrucks.com/default.aspx?pageid=255. Accessed June 29, 2008.

Disputes between cartmen, draymen, and local delivery teamsters and their employers have always exhibited the tension between employed drivers and owner-operators. The original teamsters' union, the Team Drivers International Union (TDIU), received its charter from the American Federation of Labor (AFL)[5] in 1899 and grew quickly, owing to the terrible stresses and low pay of the job. Chicago teamsters split in 1903, forming the Teamsters National Union (TNU). The dispute, in substance, revolved around the Chicago Teamsters' insistence on keeping employers out of the union,[6] so it allowed only employees and teamsters who owned and drove their own single team (without employees) to join the union.

19.2.2.2 Intercity Trucking

With a primitive highway system, the United States was ill-equipped to replace railroads with trucks. However, during the 1920s the US federal government began to build a system of interstate highways, making long-distance, individualized motor transportation feasible.

Labor was important for intercity trucking because motor carriage required intensive use of labor. Individual trucks, which even today ordinarily have at most a 50,000 pound payload, require drivers; this means that a truck and a driver can haul approximately one-third of one rail car—far lower labor productivity when measured by weight. Trucks, however, can do something railroads cannot: they can pick up shipments from widely distributed shippers and deliver them to widely dispersed consignees, which frees manufacturing and distribution from the constraints of limited fixed assets such as railroads, inland waterways, or ports. Freedom of location unleashed productive capacity, and the intercity trucking industry grew rapidly during the next 50 years.

19.2.3 Maritime and Longshoring

Maritime labor separates into two general industries: that of waterborne vessels and that of the land-based dock workers who load and unload the vessels. Waterborne vessels may be oceangoing or inland-waterway. Ocean shipping may be inter- or intra-national, and today it is organized around four broad technologies: container ships, lighter-aboard-ship (LASH) vessels, roll-on/roll-off (RoRo) ships, and tankers. *(14)* Each of these industry segments has its own work issues and skills, and draws from separate labor mar-

5 The American Federation of Labor, founded in 1886, was the primary federation or umbrella for national and international trades unions until it split in 1935 in a dispute over whether the union federation should accept workers from industrial (rather than craft) unions. The split, which took the Committee for Industrial Organization out of the AFL and created a separate union federation, the Congress of Industrial Organizations, coincided with the great growth of unionization that began with the Great Depression. The two federations were reunified in 1956. The AFL-CIO split again, however, in 2005, with the Teamsters taking a prominent role.

6 This was a reasonable concern given the notorious racketeering on the part of enterprising "leaders" who had no concern about playing both sides of the fence.

kets. Each also has its own institutional and legal framework, as well as separate competitive issues.

Seafaring work in the twentieth century began as one of the most dangerous, exploited, and low-paid occupations, but improved throughout the century due to significant institutional reforms, beginning with the Seamen's Act of 1915. The Merchant Marine Act followed in 1920 (originally codified as 46 USC Sec. 688 [the Jones Act] and recodified in as 46 USC Sec. 3010 [the New Jones Act]). It required that all ships working in cabotage between ports of the United States and its possessions must have been built in the United States and must be operated by US owners and flagged in the United States. This act also provided legal support for the broadly used claim that a ship is not seaworthy, a principal concern of merchant mariners.

Unionization took hold in the 1930s. Combined with enormous growth in the US shipbuilding industry immediately before World War I and continuing into the post-war decade, the United States quickly became the dominant presence on the seas. The US fleet went into decline beginning in about 1955. *(15)* Overbuilding in the 1960s and 1970s was followed by the early-1980s recession, which led to rapid decline of the industry and, with greatly reduced labor demand, generated very unfavorable conditions for bargaining. *(14)*

While many have blamed mandatory overstaffing for much of this decline, others argue that ships routinely are understaffed. Some analysts remain concerned that "[s]ome modest crew reductions have been based primarily on technological advances. Fewer innovations have been directed toward improving the productivity, safety, and job satisfaction of mariners. Changes that have taken place seem not to build on one another, nor have they been widely diffused throughout the industry." (*16,* pp. 4–5) Those concerned with staffing point to the *Exxon Valdez* oil spill as an example of the consequences of inadequate staffing. *(17)*

Inland waterways conceptually fuse the land-based notion of a railroad with the floating world of maritime. The workers set sail in intracoastal waterways, in the international waterways of the Great Lakes and St. Lawrence Seaway, or on major river, lock, and canal systems in various areas within the United States. They do so on tugs and barges, staffing large barge tows consisting of perhaps 15 barges containing more than 20,000 tons of freight. (*18,* pp. 148-169) Inland waterways provide one of the most labor efficient forms of intracontinental transportation, comparable to rail (2.72 ton-miles per employee for water, 474 for rail) and far more labor efficient than trucking (400,000 ton-miles per employee).[7] (*18,* p. 165)

Longshoring interacts with, but is entirely separate from, these maritime occupations. Historically dominated by cost-plus stevedoring firms that supplied labor to load and unload ships, longshoring had little incentive to inno-

7 See www.globalsecurity.org/military/library/policy/army/fm/55-50/Ch4.htm. Accessed July 11, 2008.

vate until it faced new technology. Because the shape-up system (e.g., organizing crews based on the day's work) dominated longshoring, like cartage, drayage, and intermodal trucking in the early days, work was casual and earnings indeterminate. Workers would show up at a pier, sometimes in huge numbers, for daily work. The power to assign work gave stevedoring companies, and later unions and their hiring halls, great practical leverage over workers' fates, with shape-up decisions deciding whether these casual workers would earn a living on any particular day. (*19,* p. 276)

19.3 Representation and Labor Standards

Organized labor has played a major role in the freight transport industries. This section discusses union formation and representation in the major freight sectors. It ends with a short discussion of global institutions that affect transport labor.

19.3.1 Railroads

The railroads have been represented by railroad brotherhoods—craft unions—for most of their history. The unions have been divided into nonoperating crafts and operating crafts. Five operating unions historically comprised the railroad crafts (*11,* pp. 112–114), but unions have consolidated in the past few decades as the number of operating employees declined both in response to technological change and in response to economic deregulation set by the Staggers Act of 1980, which allowed the railroads to spin off short lines and decommission unprofitable tracks and spurs. Nonoperating craft unions also developed within the railroad industry, but many of them have merged with each other and with other unions as employment declined.

Disunity among craft unions plagued union solidarity on the railroads. Railroad management could play one craft against another to the detriment of employees. America's first industrial union, the American Railway Union, ultimately was defeated as a consequence of concerted industry and government attack during the Pullman Strike, which put an end to this attempt by railroad workers to bargain collectively with railroads. *(10)* One hundred years later, however, union mergers have accomplished the same purpose. As Tables 19-1 and 19-2 demonstrate, while a single railroad employees' union does not yet exist, the number of competing craft unions has dramatically declined in the past four decades, and three major unions represent most railroad workers. Further mergers continue as industrial unions consolidate and internationalize.

Table 19-1 Railroad operating unions

Organization	History	Current Status
United Transportation Union (UTU)[a]	Formed 1969 as the consolidation of four unions	Represents 125,000 railroad, bus and mass transit workers in the United States and Canada, including conductors, brakemen, switchmen, ground service personnel, locomotive engineers, hostlers and workers in associated crafts, and railroad yardmasters
Brotherhood of Railroad Trainmen (BRT)	Originally the Brotherhood of Railroad Brakemen, changing their name in 1889	Merged to form UTU
Brotherhood of Locomotive Firemen and Enginemen (BLF&E)	Originally Brotherhood of Locomotive Firemen, changing their name in 1906	Merged to form UTU
Order of Railway Conductors and Brakemen (ORCB)	Originally the Order of Railway Conductors of America but merged in 1942 with Order of Sleeping Car Conductors and changed name in 1954	Merged to form UTU
Switchmen's Union of North America (SUNA)		Merged to form UTU
International Association of Railroad Employees	African-American union of both operating and nonoperating employees	Joined UTU in 1970
Brotherhood of Locomotive Engineers and Trainmen (BLET)[b]	Founded May 8, 1863, as the Brotherhood of the Footboard; changed name to Brotherhood of Locomotive Engineers (BLE) in 1864. The great labor leader Eugene V. Debs was general secretary-treasurer and newsletter editor from his election in 1880 until he resigned to found the American Railway Union in 1893.[c]	Represents 59,000 locomotive engineers, conductors, brakemen, firemen, switchmen, hostlers and other train service employees. Merged with Teamsters in 2004 to form Brotherhood of Locomotive Engineers and Trainmen Division

a. Attempting to merge with Sheet Metal Workers International Association (SMWIA) to create the International Association of Sheet Metal, Air, Rail and Transportation (SMART) Workers. Held up by federal court injunction as of June 26, 2008. www.utu.org. Accessed June 26, 2008.
b. www.ble.org/. Accessed June 26, 2008.
c. www.kentlaw.edu/ilhs/debstory.htm. Accessed June 26, 2008.

19.3.2 Truck Drivers in the Trucking Industry and in Other Industries

Most unionized truck drivers have been represented by the International Brotherhood of Teamsters. In addition to for-hire drayage and cartage work discussed above, teamsters were associated with the distribution function for many industries. Even today, nearly half of all trucking work and more than two-thirds of trucking employment is performed in industries other than trucking. (*20,* pp. 311–319) For example, union locals that belong to the Teamsters Warehouse Division represent grocery drivers, and the Teamsters have contracts with most major grocery store chains, grocery warehousing, and grocery distribution firms. This relationship continued as the trucking industry developed, with union membership—like the work itself—centered on narrowly focused "craft" locals that administered their own affairs. The decentralized nature of the industry and the representation characteristics that mirrored it gave the union a local

Table 19-2 Railroad nonoperating unions

Organization	History	Current Status
Transportation-Communications International Union (TCU)[a]	Amalgamation of unions	Will merge with International Association of Machinists and Aerospace Workers (IAM)[b] in 2012
Brotherhood of Railway and Steamship Clerks (BRC)	Formed in 1899 as the Order of Railroad Clerks of America, it adopted the "Brotherhood" title early on, and in 1919 took the name of Brotherhood of Railway and Steamship Clerks, Freight Handlers, Express and Station Employees. In 1967 the name changed to Brotherhood of Railway, Airline, Steamship Clerks, Freight Handlers, Express and Station Employees (BRAC).	In 1969, it merged with other railroad unions to form Transportation-Communication Employees Union (TCEU). In 1987 it became Transportation Communications International Union (TCU).
Brotherhood of Railway Carmen of America (BRCA)	Formed in 1890 and merged with BRAC in 1986	Carmen Division of TCU
Order of Railroad Telegraphers	In 1965 it took the name Transportation-Communication Employees Union; merged with BRAC in 1969.	Transportation-Communication Employees Union (TCEU), later called TCU.
Railway Patrolmen's International Union	Merged with BRAC in 1969.	TCU's Allied Services Division
American Railway Supervisors Association	Founded 1934 and broadened to American Railway and Airline Supervisors Association (ARSA); merged with BRAC in 1980.	TCU Supervisors' Division
Western Railway Supervisors Association	Formed by yardmasters on Southern Pacific in 1938 and, after twists and turns, merged with BRAC in 1983.	TCU's System Board 555
Brotherhood of Sleeping Car Porters (BSCP)	African-American union, led by A. Philip Randolph, formed in 1925 and merged with BRAC in 1978; formed Sleeping Car Porters System Division of BRAC.	TCU System Division 250
International Brotherhood of Red Caps	African-American union formed with support from BSCP, changed its name to United Transport Services Employees Union in 1942, and Red Caps and Sky Caps merged with BRAC in 1972.	TCU Allied Services Division
Railroad Yard Masters of America (RYA)	Founded in 1918, they merged in 1985 with United Transportation Union (UTU).	Part of United Transportation Union (UTU)
American Train Dispatchers Association (ATDA)	Affiliated with AFL-CIO, representing many crafts of dispatchers and other occupations, especially on short lines[c].	Independent international union in AFL-CIO
Brotherhood of Railroad Signalmen (BRS)[d]	Founded in 1901, represents 9,500 workers who install and maintain signals.	Independent member of AFL-CIO and Canadian Labour Congress
Brotherhood of Maintenance of Way Employees (BMWE)	Merged with Teamsters Rail Conference in 2004.	Teamsters Rail Conference[e]

a. www.goiam.org/tcunion. Accessed June 26, 2008.
b. www.goiam.org/iam-headquarters. Accessed June 26, 2008.
c. atdd.homestead.com/atddpg1.html. Accessed June 26, 2008.
d. www.brs.org/. Accessed June 26, 2008.
e. www.teamster.org/divisions/rail/rail.asp. Accessed June 26, 2008.

flavor, with craft membership often replicating the ethnic makeup of the relevant industries.

In addition to representation by the Teamsters, some independent unions also have represented trucking industry employees. One of these, the Chicago Truck Drivers, Helpers, and Warehouse Workers Union, is an artifact of an old split within the Teamsters and still represents mostly cartage and drayage drivers and other local employees in Chicago. Other examples include Teamsters Locals 705 and Teamsters Local 710. The International Association of Machinists (IAM) represents drivers and dock workers at at least one company. Finally, some truck drivers who work outside the trucking industry belong to the industrial unions that represent these employees; the United Auto Workers (UAW) represents truck drivers working for auto companies, for example.

The local, craft nature of representation came under duress when the Teamsters union broadened its framework during the 1930s, much to the chagrin (and with the initial active opposition) of the union's president, Daniel Tobin. Tobin attempted to prevent industrial unionism from developing within the freight sector; he wanted to keep over-the-road drivers from joining the union, consistent with the policy of the American Federation of Labor. However, a successful set of organizing and strike actions through the 1930s led to nationwide organization and representation for most truck drivers 30 years later.

19.3.3 American Maritime Unions

While labor organizations have played an important role in improving working conditions for the American merchant marine, employment on American-flagged ships has dropped to historically low levels due to technological and institutional changes. The US fleet hauls less than 5% of US international commerce—more than 50% less than in 1960—and employment declined 65–75% between 1969 and 1987. (*21,* p. 39) Most international seafaring is on flag of convenience ships staffed by international crews, as will be further discussed in Section 19.5.1. American seafarers are represented by three main unions today. Unlicensed merchant mariners working out of East and South Coast ports, along with those working in the inland waterways—including the Great Lakes—primarily east of the Rocky Mountains, belong to the Seafarers International Union, Atlantic, Gulf, Lakes and Inland Waters District/NMU, AFL-CIO (SIU). The SIU is the largest North American union representing merchant mariners[8] and has historical roots going back to its founding in 1892 and to decades of previous efforts to unionize.[9] *(22)* Unlicensed mariners are those with general levels of skill that qualify them to assist in the operation of the ship. Although mariners on inland waterways operate

8 www.seafarers.org/about/index. Accessed June 29, 2008.

9 www.seafarers.org/about/history. Accessed June 29, 2008.

wholly within the United States, they ship out for many weeks or months at a time just as do seafarers on the high seas.

Unlicensed mariners working out of the West Coast belong to the Sailors' Union of the Pacific (SUP). The SUP was formed in 1885 as the Coast Seamen's Union and in 1891 was able to overcome significant conflicts among factions to unify under the banner of the SUP.[10] The union was led by Anders (Andrew) Furuseth, whose determination and perseverance eventually led to the passage of the Seamen's Act of 1915 (the Seaman's Magna Carta) with the sponsorship of Senator Robert La Follette. The act abolished corporal punishment, gave sailors the right to leave the ship in the middle of a voyage (which previously was considered desertion, punishable by death), and generally established seamen's basic human rights. *(23)*

The Pacific Coast Marine Firemen, Oilers, Watertenders, and Wipers Association (Marine Firemen's Union), which is affiliated with the Seafarers International Union of North America, AFL-CIO, is the third major union.[11] The union has similar roots with the preceding two unions. As an affiliate of the SIU, which is a member of the AFL-CIO, the Marine Firemen's Union retains its identity but bargains together with the SIU. Finally, the International Organization of Masters, Mates & Pilots (MM&P) represents licensed mariners in four categories: offshore, inland, pilotage,[12] and government employees. The union also belongs to the AFL-CIO.

19.3.4 Globalization and International Institutions

Globalization has resulted in elaborate negotiation on commodity pricing and competitive barriers, but trade treaties resulting from these negotiations rarely consider labor or environmental issues.[13] While global labor standards have long been an important consideration, they have special salience for transport workers because their work interacts with product and labor markets throughout the world.

International labor standards are the responsibility of the International Labour Organization (ILO), a component of the United Nations. Founded in 1919 and based in Geneva, the ILO is the institution responsible for negotiating multilateral agreements for the establishment of international labor standards within the context of the United Nations. The ILO conducts research, promotes negotiations, and publicizes issues related to workers' rights and conditions of work. (*24–29*) Labor standards are voluntary, however, and nations can decide to violate them.

In the 1944 Declaration of Philadelphia, the ILO affirmed the belief of the civilized world that "all human beings, irrespective of race, creed, or sex, have

10 www.sailors.org/. Accessed June 29, 2008.

11 www.mfoww.org. Accessed June 29, 2008.

12 Licensed workers who pilot oceangoing ships into and out of harbors.

13 The North American Free Trade Agreement (NAFTA) has labor and environmental side accords, but the negotiators went back for them only after opponents showed that they would block ratification of the treaty without them.

a right to pursue both their material well-being and their spiritual development in conditions of freedom and dignity, of economic security and equal opportunity."[14] The Universal Declaration of Human Rights and the ILO's Declaration on Fundamental Principles and Rights at Work[15]—which cover freedom of association, abolition of forced labor and child labor, equality, and elimination of discrimination in employment—constitute the bedrock underlying the 185 ILO Conventions to which most member states have subscribed. However, of the 192 nations within the United Nations, the United States, Myanmar, Samoa, the Solomon Islands, Timor-Leste, and Vanatu have signed only two of these fundamental conventions (no nation has signed fewer conventions) and 14 of about 160 active conventions. In the case of the United States, the only conventions to which the United States has subscribed are Convention Number 105, "Abolition of Forced Labor Convention" (1957) and Convention Number 182, "Worst Forms of Child Labor Convention" (1999). (*30,* pp. 224–229)

The International Transport Workers Federation (ITF) represents transport workers throughout the world; it is a very large federation of 781 unions representing 4.6 million transport workers in 155 countries around the world.[16] The ITF is a member of the larger International Trade Union Confederation (ITUC),[17] representing 176 million workers employed in 151 nations[18] *(31),* which now is the only such federation representing trade unions around the world at the ILO.[19] The ITF was founded in London in 1896 by seafarers' unions attempting to represent their members on an international basis. The ITF has raised awareness of the flag of convenience problem for five decades and has successfully negotiated contracts with about a quarter of all flag of convenience carriers, representing about 123,000 mariners.[20]

19.4 US Labor Legislation

Fundamentally, the US legal system is based on two theoretical foundations: the ethics of utility and the ethics of liberty. The libertarian ethic, advocated

14 www.ilo.org/ilolex/english/iloconst.htm. Accessed February 24, 2009.

15 actrav.itcilo.org/english/about/about_fundamentals.html. Accessed February 24, 2009.

16 www.itfglobal.org/about-us/moreabout. Accessed January 13, 2011.

17 www.ituc-csi.org/spip.php?rubrique1&lang=en. Accessed July 1, 2008. The ITUC formerly was known as the International Confederation of Free Trade Unions (ICFTU). For historical continuity as well as to consolidate branding into the future, when ICFTU changed its name to ITUC, it retained its old web site: www.icftu.org/default.asp?Language=EN. Accessed July 1, 2008.

18 www.ituc-csi.org/. Accessed January 13, 2011. The ITUC historically has had a hard-and-fast rule that unions must be independent of their respective national governments, and thus Taiwan's Chinese Confederation of Labor, with 250,000 workers, still represents China at the ITUC. In January of 2008, however, the ITUC announced that it had voted (over the opposition of the US AFL-CIO) to begin discussions with the All China Federation of Trade Unions, which includes nearly 200 million workers among its members.

19 www.ilo.org/global/lang--en/. Accessed July 1, 2008.

20 www.itfglobal.org/flags-convenience. Accessed March 29, 2009.

perhaps most persuasively by John Locke and John Stuart Mill, posits that every person has a right to the product of his own labor, and the state and the society it represents cannot deprive people of their product without due process. This libertarianism is consistent with policies advocating a small state—"the government that governs best, governs least." Utilitarianism, articulated in the eighteenth and nineteenth centuries by Jeremy Bentham and also by his student, John Stuart Mill, says that economics gives us a score sheet with which to determine the ethical validity of public policy. Policies should provide for the "greatest good for the greatest number," or the total economic benefits should outweigh the total costs. Immanuel Kant, on the other hand, argued in *Critique of Pure Reason* that ethical determinations must incorporate the notion of human dignity regardless of utility, and is one of the foundations of the modern concept of human rights. The tension between these value systems expresses itself in differing expectations of the role of government and the law as guarantor of individual rights and social responsibilities related to the employment relationship. (*32,* pp. 66–81)

19.4.1 Employment Law

The body of legislative law governing the labor and employment relationship is complex and divides into two broad categories: labor law and employment law. Employment law regulates the individual in the employment relationship, and labor law regulates the individual's right to collective representation, as well as rights and responsibilities of the collective labor-representation institution[21] and the employer. Labor law further breaks down into two subsectors: public- and private-sector employment. The characteristics of public-sector law differ across jurisdictions, but for all public jurisdictions, state action gives workers rights, such as a positive First Amendment right to freedom of speech, not granted to employees of private-sector businesses in most states.[22] *(33)* At the heart of the issue is the ambiguous relationship between the state (a government entity) as an employer and the state as a sovereign government existing at the sufferance of its citizens, who may happen to be employees.

Just as an employee may quit a job at any time (a legacy of English common law as well as the 13th Amendment to the US Constitution), an employer may fire someone at any time for good reason, for bad reason, or for no reason at all, as long as the employee (or in some cases, the government) cannot prove that

21 The form of worker interest representation is not limited by law, but by custom, unions represent workers on the job. Worker interest representatives may take the form of professional associations, occupational associations, or simply mutual self-help organizations.

22 The Bill of Rights prohibits the government from restricting free speech, but absent state action, a positive right of free speech may be a state constitutional right that supersedes the limited US right. California's constitution, for example, provides for a positive free-speech right.

the discharge was due to his or her membership in a protected class (race, national origin, religion, gender, disability). (*33,* pp. 4–8; *34,* pp. 63–65) This doctrine, called employment-at-will, has become an unquestioned component of US common law, which is why it is so difficult to restrict private contract and hence employment-at-will by legislative means. The courts just rewrite the law and take away legislated rights, turning power back over to property holders. (*35,* pp. 16–35) State constitutions may restrict employment-at-will in some cases (e.g., California and Utah), but elsewhere it is prevailing law.

At an even finer grain of analysis, federal government public-sector law is quite distinct from state laws, which vary from state to state.[23] (*34,* p. 63) While most labor law relevant to multimodal transportation is private-sector-based, one must keep in mind that the rules governing unionized public-sector collective bargaining are quite different from those governing private-sector bargaining. (*33,* pp. 626–650) For example, President Ronald Reagan's response to the 1981 strike of the Professional Air Traffic Controllers Organization (PATCO), which was to fire all striking air traffic controllers and unilaterally decertify the union, would have been illegal under private-sector law. (*34,* pp. 42, 347)

Employment law applies to both the public and the private sector (*33,* pp. 51–359), although important exceptions apply to certain transport sectors. All workers ordinarily are covered by workers' compensation, for example, although coverage is defined on a state-by-state basis and frequently does not require owner-operators to buy workers' compensation insurance on the theory that they are self-employed. Almost all private-sector workers and their employers must contribute to Social Security, but an important exemption includes railroad workers, who are covered by their own pension plan that predates Social Security.

Other laws forbid discrimination against workers in protected classes, such as gender, religion, ethnic origin, age, and disability (*33,* pp. 51–228; *34,* pp. 48–74), although Supreme Court decisions have made discrimination difficult to prove in many cases.

19.4.2 Labor Law

The Fair Labor Standards Act (FLSA) of 1938 provides for the standard 40-hour workweek, with time and a half after 40 hours, and for a minimum wage, but minimum wage protections have eroded over the decades due to inflation. In addition, exemptions to the maximum hours provision of FLSA for employees of interstate trucking companies *(36)* have allowed working time of the average truck driver to balloon far beyond the previous limit of 60 hours per week at straight time or piecework *(37–39)*; in 2004, the Federal

23 Municipal public-sector law not only varies from state to state, but varies within each state at the discretion of state government.

Motor Carrier Safety Administration solved the compliance issue when it effectively raised the legal limit to 84 hours of work per week. *(40)* Employers only need to prove that truck drivers have earned the minimum wage over all hours of work (not for each hour worked) and therefore can pay only for revenue-earning time.[24] *(41)*

The Railway Labor Act (RLA) of 1926 is an entirely separate body of labor law, applicable to railroads and airlines only.[25] *(42)* The first of its kind in the United States, RLA established some basic principles, namely the notion that workers have the right to choose a union, free of threats and coercion by employers, and such unions may not be company dominated. It included a provision for a national Board of Mediation to settle disputes before they went to strike. If mediation failed, the Board of Mediation could recommend to the President that he establish an emergency board to evaluate the situation and to try to resolve it; this board had just 30 days to resolve the dispute.

Congress passed the National Labor Relations Act of 1935 (NLRA, also known as the Wagner Act) in the depths of the Great Depression, following a strike wave that gripped the nation between 1933 and 1934. Wary of the property rights and private contract ideology of the Supreme Court, Senator Robert Wagner and his allies hung the National Labor Relations Act (NLRA) on the Commerce Clause of the Constitution. Since labor disputes had already severely disrupted commerce, and since the nation could not afford continued disruption as it tried to recover from the Depression, Congress's right to regulate interstate commerce became the key to passage. It eventually became the key to getting the law to clear the Supreme Court, which it did in 1937.

The NLRA applies to all private-sector workers and has some key provisions. Section 7 declares that collective bargaining, based on worker self-organization (typically unions, but without limitation) is the preferred wage-setting mechanism. The right of employees to choose a representative (typically a union, but again without limitation) without employer coercion—a lesson learned from the RLA—was enshrined in the law. Employer unfair labor practices, again learning from the RLA, were prohibited, but unlike the RLA, the enforcement mechanism was the National Labor Relation Board (NLRB), fully reviewable by federal courts, and the penalty for violation is a make whole remedy whereby the harmed person is compensated for lost earnings.

The National Labor Management Relations Act of 1947 (NLMRA, also known as the Taft-Hartley Act) intended to reverse the gains that workers and unions had made. It created a list of union unfair labor practices, banned

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24 See United States v. Klinghoffer Brothers Realty Corp., 285 F.2d 487 (2d Cir. 1960).

25 Airlines were added in 1936.

the closed shop,[26] made secondary boycotts (strikes)[27] illegal, and allowed states to ban the union shop.[28] *(43, 44)* These amendments to the NLRA had the desired effect, as private-sector union representation peaked in the 1950s, remained stable during the 1960s, and began to decline in the 1970s. Deregulation of transportation—especially trucking—combined with aspects of the NLMRA designed to reduce workers' ability to organize unions and to weaken the Teamsters, made it extremely difficult to maintain or organize unions in trucking. *(45)* Today approximately 7% of all eligible private-sector production workers are unionized and only 9.6% of all eligible trucking industry production workers are union members; almost all of them are legacy union members—employed by firms whose existence and unionization predated trucking deregulation. Table 19-3 shows employment and the share of union membership and coverage by industry sector. Note that union density (the fraction of employees in each sector who have union representation) is high in the railroad and airline industries (where the RLA governs), moderate in the bus industry (mostly because the dominant intercity bus company, Greyhound, is unionized, as are many urban transit systems), and very low in inland waterway and trucking industries.

The most recent legislation for private-sector nonrailroad labor law is the Labor-Management Reporting and Disclosure Act of 1959 (LMRDA, also known as Landrum-Griffin Act). This law mainly provided a bill of rights for union members and introduced a provision requiring unions to provide the Labor Department with detailed annual reports that explain how its money is used; this reporting requirement is enforced. The act also requires management to report the hiring of any consultants intended to help avoid or break unions; this requirement is easily evaded and not enforced. *(47)*

19.4.3 Economic Regulation and Labor

The Interstate Commerce Act of 1887 placed the regulation of railroads in the hands of an independent commission reporting to Congress, the Interstate Commerce Commission (ICC). In brief, the ICC required that rates be com-

26 In an "open shop," workers may join a union, but even though a majority has voted for a union and the NLRB has certified it as the workers' official representative, requiring it to represent everyone in the bargaining unit, not everyone is required to join and pay dues. In a "union shop," if a union has been certified by a majority of employees in the bargaining unit, all workers must join the union or pay dues to pay for representation; the union must bargain for a union shop and management must agree to it contractually. In a "closed shop," the worker must belong to the union before being hired. Taft-Hartley made closed shops illegal, although an exemption was made later for construction at the behest of employers.

27 A secondary strike, or "boycott" (the old term for a strike), is a solidarity strike on the part of one group of workers in support of other workers. The Teamsters used the secondary boycott liberally to create the national network of unionized freight employees, and without the secondary strike it is almost impossible to organize transportation workers.

28 The National Right to Work Committee, a business organization formed in 1955, promoted then and promotes today efforts to ban union shops on a state-by-state basis. The term "right to work" is a political slogan that they created to promote the benefits of open shops.

Table 19-3 Union membership, coverage, density and employment in the transportation and warehousing industry, 2009

CIC	Industry Name	Obs	Emp.	Members	Covered	%Mem	%Cov
	Transportation & Warehousing–Total	7,110	5,398,429	1,586,515	1,697,834	29.4	31.5
6070	Air transportation	687	537,286	214,860	226,470	40.0	42.2
6080	Rail transportation	399	253,807	170,642	175,693	67.2	69.2
6090	Water transportation	101	76,546	20,405	20,405	26.7	26.7
6170	Truck transportation	1,810	1,362,909	130,923	143,109	9.6	10.5
6180	Bus service and urban transit	677	522,772	210,510	221,336	40.3	42.3
6190	Taxi and limousine service	235	187,160	16,541	16,712	8.8	8.9
6270	Pipeline transportation	72	35,250	3,219	3,321	9.1	9.4
6280	Scenic and sightseeing transportation	61	37,630	703	894	1.9	2.4
6290	Services incidental to transportation	811	630,538	111,590	122,030	17.7	19.4
6370	Postal Service	1,092	792,404	500,618	543,658	63.2	68.6
6380	Couriers and messengers	757	620,633	180,187	193,467	29.0	31.2
6390	Warehousing and storage	392	318,117	21,282	24,768	6.7	7.8

SOURCE: Cited reference *46*. ©2010 Barry T. Hirsch and David Macpherson.
CIC–2000 Census industry code: Obs – Current Population Survey sample size; Emp – wage and salary employment; Members – employed workers who are union members; Covered – workers covered by a collective bargaining agreement; %Mem – percentage of employed workers who are union workers; %Cov – percentage of employed workers who are covered by a collective bargaining agreement.

pensatory and uniform, and that a carrier demonstrate the need for service before providing it with a public and filed rate. (*37*, pp. 22–28)

The Motor Carrier Act of 1935 regulated the trucking industry similarly to the railroad industry and formally put trucking under the ICC's authority. While proponents and opponents of regulation debated the reasons for it, clearly railroads, public policy makers, and state regulatory agencies responsible for safety supported this action. Railroads thought that trucks had unfair advantages because they operated on public roads and could set rates as low as they wanted, creating the kind of destructive competition that had plagued the railroads in the nineteenth century. Policy makers supported regulation because the Depression had demonstrated the failure of unregulated markets, and they needed to reign in competition so carriers and their employees could make money. State safety agencies wanted regulation because cutthroat competition made trucks extremely unsafe, and they could not enforce their own safety regulations without impinging on interstate commerce. (*37*, pp. 51–64; *48*)

The NLRA covers merchant mariners, so to some extent their governance is the same as the rest of the US workforce. The Merchant Marine Act of 1920 (also known as the Jones Act) and the Seamen's Act of 1915 represent the foundation of labor standards legislation and the core economic regulation that governs the industry. In the case of the merchant marine industry, however, the 50-year secular downturn discussed above has eliminated most jobs for oceangoing mariners. Workers in the inland waterways—particularly those staffing large river tows—still count on the Jones Act and the NLRA to provide protection from global competition and to protect their right to organize.

After about 100 years of labor conflicts and legislation, the US freight transportation industry was operating under a system of regulation that affected not only the price and quantity of shipping services across all modes, but also employment and working conditions of transport labor. On the labor side, RLA and NRLA strengthened the bargaining position of labor and facilitated improvements in wages and working conditions. These gains came to an end with deregulation.

19.5 Economic Deregulation, Competition, and Labor

Economic deregulation reduced compensation for production workers in all transport industries, including both freight and passenger, although earnings declines were greater in some industries than others. Debate continues regarding whether the declines demonstrate that the employees had earned rents (essentially excess profits from market power) *(49–52);* whether they demonstrate the effects of collective bargaining and union bargaining power *(53, 54);* or whether lower compensation merely reflects declining human capital in the sector. *(55, 56)*

Standard economic theory suggests that workers who earn more than they would without union bargaining power are earning rents. The argument is that unions allow workers to cooperate with each other to exert market power (which companies cannot do), thereby raising compensation. By this reasoning, anything that reduces union bargaining power tends to reduce rents, and lower earnings are evidence of the loss of rents (excess wages). An alternative theory from labor economics suggests that greater compensation may demonstrate greater employee human capital, and greater compensation likely is offset to some degree by greater productivity and reduced insurance, training, and search costs. This theory suggests that while collective bargaining raises compensation, probably less than half of the higher compensation represents a rent, while the rest represents compensation for greater human capital. Industrial relations theory, in contrast, suggests that workers earn more due to union bargaining power and anything that increases bargaining power increases earnings (creates a union premium). This premium includes the value to the firm of greater human capital, greater workforce stability (lower turnover), greater workplace safety (lower workers compensation cost), reduced search and screening cost, and greater productivity. The theories are related, but distinct, and call for different policy prescriptions. As will be discussed in the conclusion, human capital theory and industrial relations (bargaining power) theory provide a foundation for the high road approach to employment relations, suggesting that corollaries of higher compensation can provide strategic advantage. Rent theory contributes to the low road approach because it assumes that labor is a commodity and therefore subject primarily to a cost minimization approach.

Regardless of the cause, research shows that economic deregulation reduced the compensation of railroad workers the least and that the railroad industry retained the highest union density, in part because railroads are highly concentrated (and railroad markets have become much more concentrated since deregulation) and in part due to RLA protections. *(57, 58)* Although the railroads spun off a significant number of short lines that either were or became nonunion, the RLA makes it virtually impossible for a major carrier to decertify its unions.

19.5.1 Impacts on Maritime Labor

Maritime labor has been affected in two ways. First, domestic water shipping continues to decline. Although the Jones Act protects maritime labor, the number of jobs is decreasing as water transport loses market share to rail.

The second impact is far more significant: the decline of the US ocean shipping industry and virtual elimination of US flag vessels in ocean commerce. As noted earlier, the flags of convenience or open registry allows oceangoing carriers to "flag out" under the flag of virtually any country, regardless of ship ownership. The carrier then operates under the regulations and laws of the flag country. Given the lower wages and lax labor restrictions of many countries and the competitive pressures within the ocean carrier industry, open registry has allowed carriers to take advantage of the lowest cost alternative, shifting business from relatively high-cost merchant marines of Western industrialized countries to low-cost labor of developing countries.

Some critics argue that open registry has compromised safety and security and has led to the development of crews of convenience that do not speak the same language. *(59)* Crews of flag of convenience carriers have become overwhelmingly Asian, the lowest cost labor market in the world. Flag of convenience ships have risen from 15% of the market in 1960 to 67% in 1987. *(72)* Chinese crews historically have been the lowest paid, costing perhaps one-tenth the cost of a Western crew (*60,* p. 77), in part a reflection of the relative per capita wealth of China compared with that of Western industrial nations. The flag of convenience, in European parlance, creates global social dumping. *(61)*

19.5.2 Cabotage and Cross-Border Trucking

The analogue for the flag of convenience repeats itself in cabotage, which is growing within trade zones throughout the world and likely will become a global phenomenon. In the European Union (EU), where cabotage is legal, trucking companies now locate operations in low-wage countries and use Conference of European Ministers of Transport (CEMT) licenses to employ drivers from poor countries to haul throughout the European Union, replacing truck drivers from wealthier nations.[29] *(62)* For freight logistics firms, these effectively are licenses of convenience (*3,* p. 383) and have become operational advantages worthy of serious marketing attention, as they provide great advantages to their holders. *(63, 64)* The trucking company's marginal advantage comes from the ability to avoid EU labor market standards *(65)*, as debated at a meeting of the European Parliament:

> Labour costs of non-EU-subjects are significantly lower than those of EU workers. According to some members of the Council, this could lead to inevitable tension within the labour market.
>
> That concern is not totally unfounded. . . .In [the transport] sector, certain international carriers make use of drivers from third countries for cross-border transport within Europe. These drivers mainly hail from Eastern Europe and beyond and put much less heavy pressure on the labour costs of a company than do their European colleagues.
>
> There are a number of reasons why non-EU drivers can be active within the Community transport market. First of all, there are international agreements, such as the CEMT, as well as bilateral agreements which grant Eastern European businesses access to the Community market. Thanks to these agreements, businesses from outside the EU are allowed to carry out international transport within the European Union, in a restricted manner or not, as the case may be. Secondly, non-EU drivers can drive Community vehicles, provided that they have the necessary licences.
>
> . . . In practice, it appears complex to verify across the EU whether the documents which a non-EU driver produces at an inspection point are the correct ones, in other words, whether this person has been employed legally and whether all social conditions have been fulfilled in the process. This difficulty has led to all kinds of practices in which non-EU drivers work for Community businesses illegally and under social conditions which are considerably worse than those enjoyed by their EU colleagues. This results in distortion of competition between EU businesses and, understandably, protests among EU drivers.[30]

In other words, the CEMT licenses allow properly licensed Eastern European drivers and even non-EU drivers to haul freight within the European Union. The complete deregulation of European trucking, which took place in 1998, led to a profusion of subcontracted, internationalized drivers working for less than three euros per hour, one-half to one-third the wage of a Greek truck driver, the lowest paid truck driver in the European Union. *(63)* As might be expected, Eastern European trucks and drivers were hauling almost 80% of all truck ton-miles by 2002 (*64,* p. 5), just a few years after liberalization and expansion of the European Union to the East.

29 See also www.ohr.int/ohr-dept/presso/bh-media-rep/round-ups/default.asp?content_id=37102 for a reference to the issue of CEMT fraud, as well as Uli Röhm and Wilfried Voigt (2006), *Tatort Autobahn. Kriminelle Machenschaften im Speditionswesen (Site of crime: Highway. Criminal conduct in the freight forwarding business)*, Frankfurt: Campus.

30 www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+CRE+20010515+ITEM-014+DOC+XML+V0//EN. Accessed July 7, 2008.

The North American Free Trade Agreement (NAFTA), a multinational trade pact covering the United States, Canada, and Mexico, has provisions permitting companies from each country to operate within the boundaries of the others. When fully implemented, it will allow individuals and companies from each country to carry freight and passengers freely between the three countries—employing drivers from whichever country they prefer—but not within the countries since NAFTA prohibits cabotage. *(67, 68, 69)* Unions, trade and safety associations, and motor carriers in each country and in small countries located adjacent to the US-Mexican border have objected because they perceive a threat to their businesses, labor markets, and public safety. For these and other reasons, implementation has been held up by administrative action, in court and subsequently by congressional intervention to prohibit use of public funds for a pilot test of the open-border policy. (*70, 71, 72* for alternative views of NAFTA)

19.5.3 Regulation of Work Practices

Trucking hours of service have been a matter of significant contention for about two decades. The Federal Motor Carrier Safety Administration (FMCSA) of the US Department of Transportation is currently responsible for hours-of-service regulations. FMCSA issued new rules effective January 2004. *(73)* The new rules limited work shifts to 14 continuous hours (clock time, regardless of breaks or type of work performed), a maximum of 11 hours of driving (increased from 10), and a 10-hour continuous break following this work shift. The rules left the maximum number of weekly hours intact (60 hours in seven days or 70 hours in eight days, for carriers operating seven days per week), but allowed the driver to use up all of the hours and resume driving and working after a 34-hour reset of the weekly clock. *(74)* A driver can work 70 hours in five days, take 34 hours off, and start to work again at midnight on the seventh day, thereby legally logging 84 hours per week. (*40,* pp. 16–22) While this may be extreme and may not be frequent, it is perfectly legal. Before the rule change, the rules required a driver who worked the full 70 hours in just five days to take three days off before resuming work.

A coalition of safety advocates and trucker representatives (the International Brotherhood of Teamsters and the Owner-Operator Independent Drivers Association) challenged the final rule in federal court, however, and the rule was overturned in July 2005 because, among other things, FMCSA had not considered the health impact on the truck drivers—which the law requires.[31] (*73,* pp. 61–64) FMCSA went to Congress and obtained a one-year delay to allow time to satisfy the court's demands, but the replacement regulation was very similar to the one that had been rejected by the court *(75),* and the court

31 Public Citizen, et al., Petitioners v. Federal Motor Carrier Safety Administration, Respondent. 2004. United States Court of Appeals for the District of Columbia Circuit. Original edition, On Petition for Review of an Order of the United States Department of Transportation. Argued April 13, 2004.

overturned it *(76)*. In December 2007, the FMCSA implemented a slightly modified regulation and placed its documents on the docket for review. *(77)* The FMCSA issued a final rule in November 2008 *(78),* which was challenged again. In December 2010, under pressure from a court-supervised agreement, FMCSA issued a new proposed rule, which modifies the "restart" provision but significantly changes the rest period requirement; it also requires that drivers take one hour of break within their 14-hour day, among other changes.

Hours of service in rail are somewhat more complex and have a longer legislative history. Originally passed in 1907 as the "Hours of Service Act," the rules were amended in 1916 to provide for an eight-hour workday[32] and provide a penalty of a fine or imprisonment or both for violation of the rule[33] (these sections were repealed later). The regulations are broken into three functional areas: train and engine service, signal service, and train order service. All three are similar in that responsibility for compliance lies with the railroad, because unlike trucking, railroad workers all work for companies engaged in rail service; owner-operators do not exist as they do in trucking.

The regulatory history is important. The law was revamped in 1969 and incorporated into the structure that remained in effect until passage of the Rail and Safety Improvement Act in 2008.[34] Those rules required that a railroad may not order a train and engine service employee to work after 12 hours on duty during a 24-hour day, including broken service, or after a 24-hour period in which the employee may not have performed 12 hours of work, without an eight-hour continuous break. The rule provided for a possible four-hour interim rest period. The minimum break was eight hours following 12 hours of continuous work or 10 hours following broken service.

The new rules address the safety problems created by the long and irregular hours provided for in the old rules. The new rules state that a train and engine service employee may not go on duty for more than 12 consecutive hours, and may not go on duty unless the employee has had at least 10 hours of rest during the prior 24-hour period. After 276 hours in any month, the railroad may not require an employee to go on duty, remain on duty, wait for deadhead transportation, or be in deadhead transportation for the remainder of the month. The rules for signal service and train order service employees are somewhat different, befitting the differences in their work. (*79,* pp. 212–13)

The National Transportation Safety Board (NTSB), which had analyzed records of train wrecks, demonstrated the obvious: the rules in effect for train and engine personnel until 2008 did not follow human circadian rhythms. In treating labor merely as labor power (a human resource), the rules encouraged unsafe practices leading to greater likelihood of fatigue-related accidents. (*79,* p. 213) Cumulative fatigue, caused by a combination of work fatigue, schedul-

32 www4.law.cornell.edu/uscode/html/uscode49/usc_sec_49_00028301----000-.html. Accessed July 11, 2008.
33 www4.law.cornell.edu/uscode/html/uscode49/usc_sec_49_00028302----000-.html. Accessed July 11, 2008.
34 www4.law.cornell.edu/uscode/html/uscode45/usc_sup_01_45. Accessed July 11, 2008.

ing irregularity, personal and family disruption, and other work-related factors, contributes to mental lapses—failures in judgment—that cause crashes. (*79,* pp. 218–19; *80)* Regulators hope that the new rules respond to these concerns and create a safer railroading environment.

Seafarers tend to work long hours, as do other transport workers, but absence from home and the fact that they live in their workplace even more strongly govern their work time. The deck officers (the master and first, second, and third mates, depending on the size of the ship's crew) rotate watches in four-hour shifts that ultimately allow them at least eight hours of unbroken time off. In 1996, the ILO adopted Convention 180 regarding hours of work for seafarers. *(28)* Article 5 addresses work and rest hours as follows:

> 1. The limits on hours of work or rest shall be as follows:
>
> (a) maximum hours of work shall not exceed:
>
> (i) 14 hours in any 24-hour period; and
>
> (ii) 72 hours in any seven-day period;
>
> or
>
> (b) minimum hours of rest shall not be less than:
>
> (i) 10 hours in any 24-hour period; and
>
> (ii) 77 hours in any seven-day period.
>
> 2. Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours...[35]

However, given competitive pressures and the fact that ILO guidelines are voluntary, it seems unlikely that these guidelines are being followed, particularly among flag of convenience carriers.

19.5.4 Independence and Dependence: Subcontracting and Employment

Independent contracting and subcontracting always have been major features of trucking. A small trucking company may consist simply of a single driver and a single truck, which he or she may own. An independent owner-operator owns and drives his own truck and operates his trucking company with his own operating authority

What constitutes true independence, and hence how contractors may be distinguished from employees, is unclear. The fact that an owner-operator books his own freight and operates on his own authority or company certification can be one measure of true independence. Data collected by the University of Michigan Trucking Industry Program (UMTIP) in 1997 and 1998 showed that approximately 74% of all over-the-road drivers are employees.

35 www.admiraltylawguide.com/conven/seafarershours1996. Accessed July 11, 2008.

The remainder are owner-drivers, about 1% of whom consider themselves employed by motor carriers, most or all of them by unionized firms. Most owner-drivers might be characterized as dependent contractors, since they work for motor carriers to which they are permanently leased.[36] The UMTIP data suggest there are few truly independent operators.

The term owner-operator has become politically charged, as a result of controversies regarding the use of contractors by motor carriers. The implications embedded in the concept led to a successful challenge to unionization of owner-driver steel haulers who had decertified the Teamsters and attempted to certify their representation by the Fraternal Association of Steel Haulers (FASH) in 1970. In this case, the motor carrier that opposed the effort by FASH to represent former Teamster drivers argued that the law did not require the company to recognize a majority vote in favor of representation by FASH because the drivers actually were self-employed independent contractors.[37]

Recently, local delivery drivers for FedEx successfully challenged their classification as owner-operators. Although they own their own panel trucks, they must buy their trucks from a manufacturer that FedEx specifies, paint the trucks in a specified way to identify them as part of an apparently seamless FedEx brand, buy repair and other services from FedEx, park their trucks overnight and on weekends in FedEx facilities, and work exclusively for FedEx. A California court ruled that these drivers actually are employees who own their own trucks and should properly be entitled to protection as employees.[38] In December 2008, the court awarded $27 million in back pay. The Internal Revenue Service (IRS) has also ruled that these truck drivers were misclassified as owner-operators and ordered FedEx to pay $319 million in back taxes and penalties. *(81)*

Distinguishing between dependent and independent contractors requires careful analysis. An independent contractor operates under its own authority, locates its own freight, and manages its affairs on its own. A dependent contractor operates under another motor carrier's authority, hauls that motor carrier's freight, and is managed to a certain degree by that motor carrier. Under new federal regulations, independent business owners who had previously been considered employees that leased their trucks to a motor carrier can now operate without having to invest in rolling stock, but also retain the

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36 Typically a permanent lease has a thirty-day termination clause, exercisable by either party. The owner-driver with such a lease usually may only haul freight for the carrier to whom he is contracted.

37 Three cases helped to establish these legal precedents.
1. United States Steel Corp. v. Fraternal Association of Steelhaulers, F.2d 1046 (3d Cir. 1970).
2. 1970 US Dist. LEXIS 11685. United States District Court for the Western District of Pennsylvania. Original edition, May 15, 1970.
3. Conley Motor Express v. Russell, et al. 500 F.2d 124; 1974 US App. LEXIS 7820.

38 Anthony Estrada et al., Plaintiffs and Appellants, v. FedEx Ground Package System, Inc., Defendant and Appellant. B189031. Court of Appeal of California, Second Appellate District, Division One. 154 Cal. App. 4th 1; 64 Cal. Rptr. 3d 327; 2007 Cal. App. LEXIS 1302; 154 Lab. Cas. (CCH) P60, 485.

status of covered employees with the right to workers compensation insurance, standardized company wages and benefits, and the right to collective bargaining.

19.6 Labor Strategies and Their Consequences

Transportation labor relations can take the high road or the low road. The high road generally is characterized by decent pay and working conditions, where "decent" remains vaguely defined by ILO and domestic labor standards *(82)* and may include unionization. Other characteristics include pay for knowledge, pay for safety, pay for performance, pay for stability, and a general preference for up-skilling (productivity enhancing technology that relies on human skills and judgment and encourages skill development and education). These approaches lead to the professionalization of transport operators and to higher compensation. They also are consistent with a perspective on supply chain that considers the logistics function to be value added and not merely a cost center.

The alternative often is called the low road. The low road is based on the commoditization of labor power—consideration that labor power is an input of production, the cost of which must be minimized as part of the production function. It includes contingent compensation (activity-based pay, rather than time-based pay), subcontracted labor (owner-drivers, owner-operators, leased labor, and other forms of contingent employment relationships), part-time labor, and immigrant labor. De-skilling, the implementation of technology that enables replacement of skilled labor with unskilled labor, tends to accompany the low road approach. Employers seeking the low road will do whatever it takes to remain nonunion because represented labor almost always costs more than unrepresented labor.

Unregulated or highly competitive markets militate against the high road. If higher wages and better working conditions add to costs, these additional costs may be difficult to maintain while preserving a stable market position. The transport sector may be particularly vulnerable to destructive competition, leading to constantly declining prices (and hence wages) and instability of firms. Today's freight transport labor issues suggest that the United States is following the low road.

19.6.1 Hours of Service

Almost all transportation employees have disruptive schedules, and many of them work very long hours away from home. Truck drivers, and especially over-the-road drivers, experience long working hours, substantial time away from home, irregular work schedules and working time, contingent work and compensation, and low pay. *(37, 38, 39, 56)* Railroad workers and airline employees—especially pilots and flight attendants—experience similar problems of long hours and irregular schedules that compromise health. Finally, maritime workers on both inland waterways and overseas routes work long hours and continuous days, with inland waterway workers subjected to a six-on, six-off schedule for 24-hour periods, seven days a week, which leads to potentially unhealthy disruptions in circadian rhythm. There is evidence that long and irregular hours, as well as night work, endangers health. *(73, 40)*

The incoming workforce does not appear to be willing to tolerate these conditions. Some critics argue that the FMCSA's current hours-of-service regulations are an implicit admission that it is unable or unwilling to gain compliance with the existing work time regulations.[39] Long hours of work may exacerbate the turnover or churning problem and drive more workers away from the industry *(83),* compounding the problems created by the apparent shortage of truck drivers. Dramatic cuts in airline compensation and increased work hours and responsibilities may reduce labor supply and lead to labor shortage problems in that sector, as well.

19.6.2 Safety

Safety is a public policy concern because the workplace of the transport worker is the public highway, public waterway, rail right of way, airspace, or airport. The safety issue is complex to analyze because technological, demographic, and organizational factors muddy the picture. Public policy demands safer highways *(84–90)* in part because exposure has increased and in part because the public's expectation for safety has increased. More than 5,000 truck drivers die every year in fatal truck crashes *(91),* and although trucking does not have the highest worker death rate among industries, it has the second-highest number of on-the-job deaths, behind construction. *(92)* Just-in-time logistics and 24/7 scheduling puts great pressure on truck driver performance. Competitive pressures have been intense for three decades and likely will remain so, absent fundamental regulatory change, putting added pressure on motor carrier safety. Competition in the trucking industry is associated with lower wages, and low compensation is associated with compromised safety. *(56, 93)* Similar problems face the inland waterway and railroad sectors *(94, 95),* as pressure on freight rates and productivity stress the freight transportation sector generally and workers in particular. Fatigue and other issues beset the airline industry (*96, 97*) and the motor coach industry, as well.

39 See Federal Motor Carrier Safety Administration Docket No. FMCSA 2004-19608. Hours of Service of Drivers; Interim Final Rule; Request for Comments. 72 FR 71247, December 17, 2007. Comments Filed Jointly by Advocates for Highway and Auto Safety, International Brotherhood of Teamsters, Public Citizen, and the Truck Safety Coalition. March 17, 2008.

19.6.3 Health

Health is a public policy issue because poor health outcomes raise costs, create negative externalities, and dissipate the skilled workforce. Research suggests that long work hours and sleep disruption causes significant health problems. Poor chronic health outcomes are costly to society and to working families, reduce development, and discourage a prospective workforce. Preliminary research suggests that truck drivers may die earlier than other similarly situated workers in other occupations. (*98,* pp. 5–13) Indeed, research suggests that the stress hormones that keep truck drivers alive in the short run also reduce life expectancy in the long run by producing a chain reaction of insulin suppression, weight gain, and cardiovascular disease. (*40,* pp. xiii; *46–53*; *60–64*) Health issues in other transport modes parallel those in trucking—e.g., long hours, irregular schedules, and sleep deprivation.

19.6.4 Demographics and the Labor Shortage

Trucking deregulation caused hundreds of established unionized motor carriers to disappear, and a restructured industry developed out of the exempt, specialized, and contract carrier sector. *(53, 99)* Industry restructuring led to a transformation of labor markets, including rapid deunionization. *(54)* It also led to a chronic labor shortage that has persisted for more than two decades.

The American Trucking Associations commissioned two studies that provided evidence of the industry's labor shortage. *(83, 100)* The most recent study, conducted by Global Insight, projects that US labor force growth will slow from 1.4% to 0.5% annually through 2012 even as the demand for truck drivers increases 2.2% per year (assuming growth rates projected in 2005, before the severe and prolonged economic downturn underway at the time of this writing and projected throughout that forecast period). While a growing number of Hispanic workers will become part of the trucking industry's workforce demographic, the number of available 35–40 year-old male workers will decline. In addition, trucking will still face an enormous labor market churn, with much of the hiring and recruiting activity aimed at poaching skilled labor from other trucking companies. To meet the expected demand, trucking must attract labor from other occupations, but long hours, low compensation, and difficult working conditions present great challenges to doing so. *(83)*

Evidence suggests that the quality of the workforce has declined since deregulation, with fewer qualified drivers available and willing to work for the compensation packages trucking companies can offer. *(101, 102)* Indeed, research suggesting that driver compensation is associated significantly with driver safety *(56, 93, 103)* is consistent with earlier research suggesting that declining compensation since the mid- to late-1970s has led to declining workforce quality.

Economists argue that labor shortages do not exist in a competitive market because compensation and other aspects of employment packages should rise to attract labor. In industries subject to excessive or destructive competition, however, this is not necessarily the case. There is evidence in the trucking industry that carriers that have tried to raise compensation to reduce turnover and hire experienced truck drivers were unable to do so due to the competitive environment. *(56, 103)* It may be that domestic deregulation of freight industries, deregulation of labor markets, and deregulation of global trade have led to a perfect storm in which pricing pressure from shippers and pricing at marginal cost make it impossible for any individual firm to rise above the destructive competition to solve the resulting labor shortage.

19.6.5 Security

Security presents many of the same problems as safety. One might argue that there is little incentive for transport firms and shippers to invest in security when prices are based on short-run marginal costs, incomplete information, and short time horizons. The US Department of Homeland Security has determined that the Transport Worker Identity Credential (TWIC) is a necessary security measure to verify that those people who have access to ports—including dock workers, port truck drivers, and others—are who they say they are. Applications for TWICs entail cumbersome and time-consuming investigations, and many of the people working in the ports will not qualify, exacerbating workforce challenges. *(104–107)* The labor market implications for TWIC are substantial, as it will reduce an already thin workforce, especially in drayage, yet it is by no means clear that the workforce squeeze will translate into compensation improvements sufficient to draw the necessary labor.

19.6.6 Cabotage

NAFTA provides for transnational motor carrier ownership within North America. While it does not formally allow cabotage, motor carriers can effectively engage in cabotage either by routing freight across the border and back, when convenient, or by subcontracting to domestic firms employing low-wage immigrant labor. As with seafaring, absent the effects of the Jones Act, will this lead to the replacement of US truck drivers with foreign—mainly Mexican—truck drivers, similar to what has happened within the European Union? This is a variant on the immigration theme generally, since immigrants working in international transportation do not have to pay the high US cost of living and therefore can provide for their families at home even as shippers (and consumers) pay lower freight rates based on transnationalization of the workforce. In the case of transportation, once free trade among countries within the same transnational trading block is internationalized, international carriers from the wealthier nations can replace their entire transportation workforce with workers from poor countries within the same trans-national trading block until labor cost is minimized at the level of the poorest country. *(108–111)*

19.7 Conclusions

Today's workforce problems are embedded within the larger context of deregulation and globalization. While consumers have greatly benefited from lower prices and the economic growth associated with international trade, transport labor has not been so fortunate. As long as real compensation continues to decline, we can anticipate declining quality and availability of the transport workforce. This chapter has shown that labor problems exist across all transport sectors, with the notable exception of the railroads, where labor has benefited from limited competition and institutional protection provided by the RLA. Absent significant changes in national and international labor policy, safety and health problems are likely to increase. Indeed, social regulation—regulation of safety, health, and environmental externalities—can be expected to become a major focus of attention for carriers, drivers (and pilots and engineers), labor and professional associations, and trade associations concerned with freight transport. Safety and health consciousness are direct consequences of wealth. Wealthy societies tend to put these concerns high on their policy preference list, so we should expect social regulation to continue to take the place of the economic regulation of a previous era.

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Mr. Cudahy has published 16 books on various aspects of transport history. His work of the New York subway, *Under the Sidewalks of New York,* was honored as one of the top ten best sellers at the centennial celebration of Fordham University Press. His most recent work, *Box Boats,* is a thorough history of the containership industry.

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His recent work has concentrated on performance measures for congestion and operations, especially in the area of travel time reliability, including NCHRP Project 3-68, *Guidebook for Freeway Performance Measures,* SHRP2 Project L03, *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies,* and FHWA's *Mobility Monitoring Program*. He has also conducted several national studies of highway bottlenecks for the American Highway Users Alliance, Ohio DOT, the FHWA Office of Freight, and the I-95 Corridor Coalition.

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Bruce Wang is currently an assistant professor of transportation engineering in the Department of Civil Engineering at the Texas A&M University. With 18 years of research in freight logistics, Dr. Wang has experience in railroad, airlines, and trucking operations. His technical expertise includes network modeling applied to freight distribution and transportation logistics.

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Abbreviations

3PL	third-party logistics
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACI	Airports Council International
ACS	American Community Survey
ACSD	Advanced Container Security Device
ACTA	Alameda Corridor Transportation Authority
AFL	American Federation of Labor
AIP	Airport Improvement Program
AIS	automatic identification systems
AMP	alternative marine power
AMT	alternative minimum tax
APL	American President Lines
ARU	American Railway Union
ATA	American Trucking Associations
ATLF	advanced truckload firm
ATO	assemble-to-order
ATSA	Aviation and Transportation Security Act
BOAC	British Overseas Airways Corporation
CAB	Civil Aeronautics Board
CAFTA	United States–Dominican Republic–Central America Free Trade Agreement
CBP	US DHS Customs and Border Protection
CCSF	certified cargo screening facility
CCSP	Certified Cargo Screening Program
CEMT	Conference of European Ministers of Transport
CEQ	US Council on Environmental Quality
CGPCS	Contact Group on Piracy off the Coast of Somalia
CFS	Commodity Flow Surveys
CLM	Council of Logistics Management
COFC	container-on-flat-car
COG	center-of-gravity model
CREATE	Chicago Region Environmental and Transportation Efficiency
CSCMP	Council of Supply Chain Management Professionals
CSI	Container Security Initiative
C-TPAT	Customs Trade Partnership Against Terrorism
DCs	distribution centers

DHS	US Department of Homeland Security
DLP	deterministic linear programming
DOE	US Department of Energy
dwt	deadweight tons
EDI	electronic data interchange
EIS	environmental impact statement
EMP	equipment management program
EMS	Environmental Management System
EOBRs	electronic on-board recorders
EOQ	economic order quantity
EPA	United States Environmental Protection Agency
EU	European Union
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FASH	Fraternal Association of Steel Haulers
FAST	Free and Secure Trade program
FCFS	first-come, first-served
FDI	foreign direct investment
FedEx	Federal Express
FEU	40-foot equivalent unit
FHWA	Federal Highway Administration
FLSA	Fair Labor Standards Act
FMC	Federal Maritime Commission
FMCSA	Federal Motor Carrier Safety Administration
FOC	flag of convenience
FRA	Federal Railroad Administration
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information systems
GPS	global positioning systems
GVW	gross vehicle weight
HDDT	heavy duty diesel trucks
HMTF	Harbor Maintenance Trust Fund
HOS	hours of service
HOV	high-occupancy vehicle
HPMS	Highway Performance Monitoring System
IATA	International Air Transport Association
IBU	intermodal business unit
ICAO	International Civil Aviation Organization
ICC	Interstate Commerce Commission
ICTSI	International Container Terminal Services Inc.
ILO	International Labour Organization
IMCs	intermodal marketing companies
IMF	International Monetary Fund
IMO	International Maritime Organization
IPPC	Intergovernmental Panel on Climate Change
IRS	Internal Revenue Service
ISO	International Organization for Standardization
ISPS Code	International Ship and Port Facility Security Code

ISTEA	Intermodal Surface Transportation Efficiency Act
IT	information technology
ITF	International Transport Workers Federation
ITUC	International Trade Union Confederation
IWTF	Inland Waterways Trust Fund
JIT	just-in-time
LASH	lighter-aboard-ship
LCL	less-than-carload
LCV	longer combination vehicle
LOS	level of service
LTL	less-than-truckload
MAC	Metropolitan Airports Commission
MARAD	Maritime Administration
MARPOL	International Convention for the Prevention of Pollution from Ships
MATTS	Maritime Asset Tag Tracking System
MCMIS	Motor Carrier Management Information System
MPO	metropolitan planning organization
MSC	Mediterranean Shipping Company
MTS	marine transportation system
MTSA	Maritime Transportation Security Act
MTOs	marine terminal operators
NAAQS	National Ambient Air Quality Standards
NAFTA	North American Free Trade Agreement
NAICS	North American Industrial Classification System
NCTCOG	North Central Texas Council of Governments
NEPA	National Environmental Policy Act
NIEs	newly industrializing economies
NLMRA	National Labor Management Relations Act
NLRA	National Labor Relations Act
NLRB	National Labor Relation Board
NNSA	US DOE’s National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
NVOCC	Non-Vessel-Operating Common Carriers
NYMTC	New York Metropolitan Transportation Council
O-D	origin-destination
OECD	Organization for Economic Cooperation and Development
OOIDA	Owner-Operator Independent Drivers Association
OPEC	Organization of Petroleum Exporting Countries
PABs	private activity bonds
PFC	Passenger Facility Charge
PHMSA	Pipeline and Hazardous Materials Safety Administration
PM	particulate matter
PPP	public-private partnership
REA	Railway Express Agency
RFID	radio frequency identification
RFS	road feeder services
RLA	Railway Labor Act
RRIF	Railroad Rehabilitation and Improvement Financing
RoRo	roll-on/roll-off

SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SBS	satellite-based systems
SFBs	special facility bonds
SIC	Standard Industrial Classification
SOLAS	International Convention for the Safety of Life at Sea
SSAS	ship security alert systems
STB	Surface Transportation Board
TAPA	Transported Asset Protection Association
TAZs	traffic analysis zones
TDIU	Team Drivers International Union
TEA-21	Transportation Equity Act for the 21st Century
TEU	20-foot equivalent unit
THC	total hydrocarbon
TIFIA	Transportation Infrastructure Finance and Innovation Act
TIP	Trucking Industry Program
TL	truckload
TNCs	transnational corporations
TNU	Teamsters National Union
TOFC	trailer-on-flat-car
TSA	Transportation Security Administration
TTI	Texas Transportation Institute
TWIC	Transportation Worker Identification Credential
ULCC	ultra large crude carrier
ULDs	unit load devices
UMTIP	University of Michigan Trucking Industry Program
UNCLOS	United Nations Convention on the Law of the Sea
UP	Union Pacific Railroad
UPS	United Parcel Service
USCG	US Coast Guard
USDOT	United States Department of Transportation
USLD	ultra-low sulfur diesel
USPS	United States Postal Service
UTU	United Transportation Union
VHF	very high frequency
VIUS	Vehicle Inventory and Use Survey
VMT	vehicle miles of travel
VSAs	vessel sharing agreements
WCO	World Customs Organization
WME	weapons of mass effect
WTO	World Trade Organization

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