Freight Intermodal Connectors Study

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16. Abstract

The objective of this study is to provide a comprehensive understanding of the condition and performance of the nation's freight intermodal connectors. This approach extracts connector data from Federal, State, and local sources to understand the operations of freight connectors relative to the broader freight transportation system. It also includes 18 case studies to perform a deep-dive into planning, stakeholder, and funding elements that are specific to freight intermodal connectors. The results of the study are used to estimate the additional operating costs associated with using freight intermodal connectors due to current pavement and bottleneck conditions.

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
AADTT	Average Annual Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
BNSF	Burlington Northern and Santa Fe
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CMP	Congestion Management Plan
DOT	Department of Transportation
EDA	Economic Development Administration
FAA	Federal Aviation Administration
FAST	Freight Action Strategy
FASTLANE	Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GARVEE	Grant Anticipation Revenue Vehicles
GIS	Geographic Information Systems
HERS	Highway Economic Requirements System
HERS-ST	Highway Economic Requirement System—State Version
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program
ICAT	Intermodal Connector Assessment Tool
IRI	International Roughness Index
LRTP	Long-range Transportation Plan
MAP-21	Moving Ahead for Progress in the 21st Century Act
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NHFN	National Highway Freight Network
NHFP	National Highway Freight Program
NHPP	National Highway Performance Program
NHS	National Highway System
NMFN	National Multimodal Freight Network
NPMRDS	National Performance Monitoring Research Data Set
SIS	Statewide Intermodal System
STBG	Surface Transportation Block Grant Program
STIP	Statewide Transportation Improvement Programs
TEA-21	Transportation Equity Act for the 21st Century
TEU	Twenty-foot Equivalent Unit
TIFIA	Transportation Infrastructure Finance and Innovation Act

TIP	Transportation Improvement Program
VMT	Vehicle Miles Traveled

CHAPTER 1. INTRODUCTION

Highway intermodal connectors are roads that provide the "last-mile" connection between major rail, port, airport, and intermodal freight facilities on the National Highway System (NHS). The officially designated network of NHS intermodal connectors accounts for less than one percent of total NHS mileage, but these roads are critical for the timely and reliable movement of freight.[1] It is, therefore, important to understand the use, condition, and performance of the Nation's intermodal connectors since they have a direct impact on goods movement efficiency and, therefore, the health of the economy.

This report comprises a review of the existing and emerging literature and data sources for assessing intermodal connectors in the United States. The goal is to help the United States Department of Transportation (USDOT) understand how freight intermodal connectors currently are being used by industry; how that use is changing due to emerging logistics trends, and what the implications are for existing designated intermodal connectors; the available data and resources to assess the performance of freight connector routes; and any "lessons learned" from recent experiences in successfully improving freight intermodal connectors. The results of this work will inform future tasks in this project, including case study selection and the assessment of intermodal connector condition and performance.

The remainder of this report is organized as follows:

- Extent of the **existing designated NHS Intermodal Connector system** is described in **Chapter 2**, as well as the historical policy context and previous assessment of the system's condition and performance.

- Key existing and emerging **freight and logistics trends**, and how they are likely to impact freight intermodal connectors in the future are detailed in **Chapter 3**.

- Current **state of the practice** in evaluating freight connector performance, including Federal, State, and local databases and modeling tools, as well as performance measures, are reviewed in **Chapter 4**.

- Recent experience in **improving freight connector routes** is reviewed in Connector **Chapter 5**, which also presents innovative approaches and key "lessons learned."

For this study, available information on freight intermodal connectors was organized under three broad topic headings: 1) connector use; 2) performance; and 3) solutions. This report focuses on the information that is most relevant to USDOT for Federal policy development and program management.

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[1] FHWA Freight Management and Operations NHS Connectors, http://www.ops.fhwa.dot.gov/Freight/infrastructure/nhs_connect/index.htm.

HISTORICAL POLICY CONTEXT

The National Highway System Designation Act of 1995 (Public Law 104-59) directed the Secretary of Transportation to develop a list of NHS intermodal connectors and submit it to Congress for approval. This inventory was completed in 1998 and approved by Congress as part of the Transportation Equity Act for the 21st Century (TEA-21).

NHS Intermodal Connectors are defined as “roads that provide access between major intermodal facilities and the other four subsystems making up the National Highway System.”[2] The four subsystems are: 1) Interstates; 2) Other Principal Arterials; 3) the Strategic Highway Network; and 4) Major Strategic Highway Connectors. Public roads that lead to major intermodal hubs are designated NHS connectors by the USDOT in consultation with State Departments of Transportation (DOTs) and metropolitan planning organization (MPO) partners.

In 2009, the FHWA developed a database, the Intermodal Connector Assessment Tool (ICAT), to facilitate reassessments of the condition and performance of intermodal connectors.

CURRENT NATIONAL HIGHWAY SYSTEM FREIGHT INTERMODAL CONNECTOR SYSTEM

At the end of 2014, there were 950 designated NHS connectors spanning 1,407 miles of roadways, connecting 798 freight intermodal facilities to the national highway network.[3] This compares with 616 designated connectors in 1998. Most of this increase was the result of 10 States that designated many more of their roadways as NHS freight intermodal connectors. These 10 States added 130 of the 182 (70 percent) new freight intermodal connectors between 2000 and 2014. This increase in connectors has occurred as many States have proposed modifications and additions to the designated system. These changes are considered by the Federal Highway Administration (FHWA) based on the same criteria used to identify the initial system in 2000. The primary criteria are based on annual freight volumes, or daily vehicular traffic on one or more principal routes that serve the intermodal facility. The secondary criteria are intended to highlight the importance of an intermodal facility within a specific State. Table 1 presents the freight-related criteria.

Table 1. Number of Freight Intermodal Connectors by Mode—2000 to 2014.

Mode	2014 Connectors	2000 Connectors	Net Change	Percentage Change
Port	329	252	77	31%
Rail	269	204	65	32%
Airport	132	99	33	33%
Pipeline	68	61	7	12%
Total	798	616	182	30%

[2] FHWA Freight Management and Operations NHS Connectors, http://www.ops.fhwa.dot.gov/freight/infrastructure/nhs_connect/index.htm.

[3] FHWA Freight Management and Operations Freight Connectors Summary and Updates, http://www.ops.fhwa.dot.gov/Freight/freight_news/nhs_connectors.htm.

Table 2. Criteria for Adding to or Modifying the National Highway System (NHS) Intermodal Connector Subsystem.

	Criteria
Primary Criteria	**Airports—**100 trucks per day in each direction on the principal connecting route; or 100,000 tons per year arriving or departing by highway mode. **Ports—**Terminals that handle more than 50,000 20-foot equivalent units (TEU) per year, or other units measured that would convert to more than 100 trucks per day in each direction; or bulk commodity terminals that handle more than 500,000 tons per year by highway or 100 trucks per day in each direction on the principal connecting route. **Truck/Rail—**50,000 TEUs per year, or 100 trucks per day, in each direction on the principal connecting route, or other units measured that would convert to more than 100 trucks per day in each direction. **Pipelines—**100 trucks per day in each direction on the principal connecting route.
Secondary Criteria	Intermodal terminals that handle more than 20 percent of freight volumes by mode within a State. Intermodal terminals identified either in the Intermodal Management System or the State and metropolitan transportation plans as a major facility. Significant investment in, or expansion of, an intermodal terminal. Connecting routes targeted by the State, metropolitan planning organization (MPO), or others for investment to address an existing, or anticipated, deficiency as a result of increased traffic.

(Source: 23 CFR 470, Appendix D.)

CHAPTER 2. TRENDS IMPACTING FREIGHT INTERMODAL CONNECTORS

Changes in logistics strategies and supply chains have affected the types and volumes of traffic on freight intermodal connectors in addition to creating new intermodal hubs. This chapter discusses several key trends in freight and logistics and their ongoing impact on the Nation's intermodal connectors. The key trends examined in this chapter are:

1. Continued globalization and increasing global consumer population.
2. Global manufacturing shifts, including near-shoring/resourcing.
3. Emergence of e-commerce fulfillment centers.
4. New sources of domestic oil and gas.
5. Emerging use of liquefied natural gas as a marine transport fuel.
6. Panama Canal expansion accelerating the use of ultra-large ships.

It is likely that trends in the overall economy and logistics patterns will continue to shift the usage of freight intermodal connectors across the U.S. The modes that will be most heavily impacted are rail and deep-sea marine as increased global populations, changes in manufacturing competitiveness, increased use of fulfillment centers, and the expansion of the Panama Canal combine to alter how these modes are utilized for domestic and international supply chains. Truck-truck facilities will also be heavily impacted by these developments as freight continues to cluster in more specific locations in metropolitan regions across the U.S.

Intermodal connectors to inland waterway ports, air cargo facilities, and pipelines will be somewhat less impacted by these trends. Overall, the continued fluidity in the usage of freight intermodal connectors will result in truck volumes that will increase significantly on some connectors and decrease significantly on others. Additionally, new connectors will continue to emerge, and some older connectors will cease to be utilized at all.

Table 3 summarizes the impacts of the six freight trends on freight intermodal connectors for each of the major freight modes.

Table 3. Summary of Impacts of Trends on Intermodal Connectors for Each Mode.

Economic or Logistics Trend	Rail	Deep-Sea Marine	Inland Waterway	Air Cargo	Pipeline	Truck-Truck Facilities
Globalization and Consumer Population	Very Significant Impact	Very Significant Impact	Little Impact	Very Significant Impact	No Impact	Very Significant Impact

Table 3. Summary of Impacts of Trends on Intermodal Connectors for Each Mode (continuation).

Economic or Logistics Trend	Rail	Deep-Sea Marine	Inland Waterway	Air Cargo	Pipeline	Truck-Truck Facilities
Global Manufacturing Shifts	Very Significant Impact	Very Significant Impact	Very Significant Impact	Significant Impact	Little Impact	Very Significant Impact
Fulfillment Centers	Very Significant Impact	Very Significant Impact	No Impact	Some Impact	No Impact	Very Significant Impact
Domestic Oil and Gas	Very Significant Impact	Very Significant Impact	Very Significant Impact	No Impact	Very Significant Impact	Some Impact
Liquefied Natural Gas as a Marine Transport Fuel	No Impact	Little Impact	Little Impact	No Impact	Some Impact	No Impact
Panama Canal	Very Significant Impact	Very Significant Impact	Significant Impact	No Impact	Some Impact	Very Significant Impact

FREIGHT INTERMODAL TERMINALS AND TRAFFIC VOLUMES

Port Terminal Traffic

Figure 1 shows port intermodal container traffic from 1970 to 2014. Containerized traffic at U.S. ports increased from 30 million twenty-foot equivalent units (TEUs) to 45 million TEUs since the initial designation of port intermodal connectors in 2000. The Association of American Railroads reported that approximately 9 million TEUs of port intermodal containerized traffic was moved by rail. Therefore, it can be estimated that roughly 36 million TEUs (80 percent) of the port international traffic used highway connectors between the port and inland locations in the U.S.

Rail Terminal Traffic

There were approximately 189 intermodal rail terminals in the U.S. handling either container on flatcar or trailer on flatcar as of 2010.[4] The vast majority of the 2,270 rail facilities in the U.S. are designed to service industrial, resources, or manufacturing needs for bulk and break-bulk shipments.

Rail intermodal traffic has increased significantly over the past 25 years with a moderate decline occurring between 2007 and 2009 as a result of the most recent recession. The volume of containers and trailers moved on the railroads annually has more than doubled since 2000, rising

[4] University of Hoftra, The Geography of Transport Systems, https://people.hofstra.edu/geotrans/eng/ch4en/appl4en/na_intermodalrailterminals.html.

from about 6 million annually in 2000 to nearly 13 million in 2013. Over that same time period, trailers decreased from half to around 15 percent of total intermodal flows (Figure 2). Rail intermodal traffic has increased by nearly 50 percent (roughly the same increase as containerized port traffic) since the initial designation of the National Highway System (NHS) freight intermodal connectors. Accommodating this growth in intermodal rail volumes has been achieved through a combination of expanding existing rail intermodal terminals and adding new terminals. This can be contrasted with the deep sea ports, which have accommodated new cargo volumes almost exclusively through expansion and modernization of existing facilities.

Air Cargo Terminal Traffic

The landed weight of all air cargo operations decreased from 2000 to 2012 from 74.7 million tons to 67.5 million tons (Figure 3). The lowest volume of tonnage occurred in 2009 with 63.2 million tons. Changes in truck volumes on airport intermodal connectors are likely to mirror the changes in the air cargo tonnages with slight dip in truck volumes since the 2000 designation of NHS intermodal connectors.

Pipeline Terminal Traffic

Pipeline-to-truck movements are dominated by tanker trucks using roadways to travel between gasoline tank farms and retail gasoline stations. Therefore, the usage of pipeline intermodal connectors is correlated to gasoline consumption. Due to increased fuel efficiency, gasoline consumption in the U.S. peaked in 2007 at 142.3 billion gallons and 2013 gasoline consumption is still lower than the 2002 consumption level.[5] The peaking of gasoline consumption indicates that the total demand for pipeline-truck intermodal connectors is also not likely to have increased significantly since they were designated in 2000. Consistent with this theme, overall liquid pipeline movements had limited growth since 2000 until the 2011 to 2013 period when crude oil pipeline shipments increased from 7.0 billion barrels to 8.3 billion barrels (Figure 4).

The recent increase in domestic output of oil and gas, as well as the recent lifting of the crude oil export ban by the U.S. Congress may result in shifts in the volumes of trucks on specific pipeline intermodal connectors, even as the overall truck volume remains relatively flat. However, much of the shale-based oil is not transported via pipelines due to lack of availability.

[5] American Fuels, American Fuels News and Commentary, 2013 Gasoline Consumption, http://www.americanfuels.net/2014/03/2013-gasoline-consumption.html.

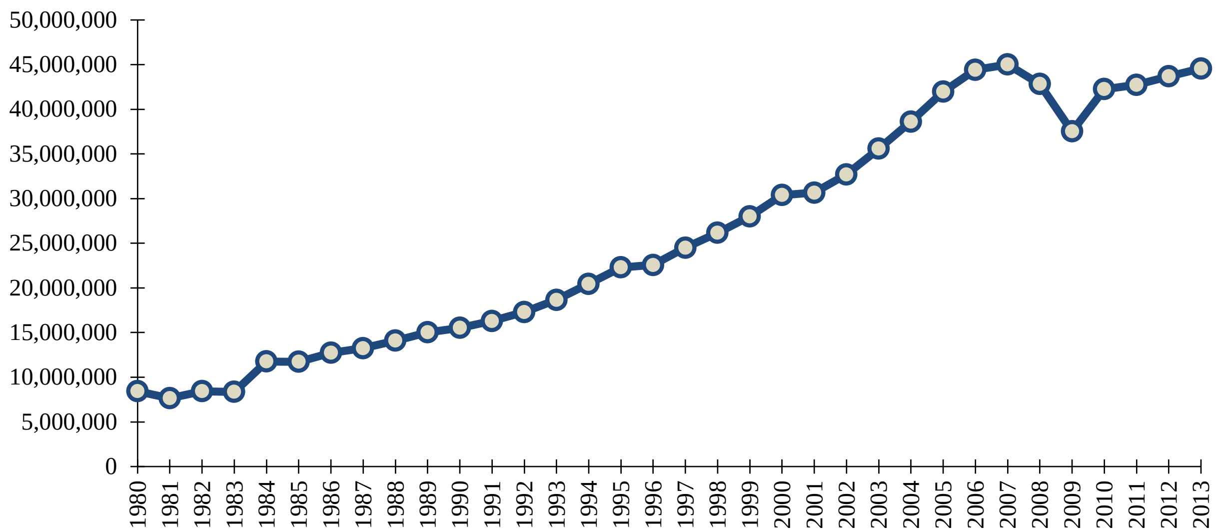

Figure 1. Graph. Containerized Traffic at U.S. Ports, 1980 to 2013—In Twenty Foot Equivalent Units.
(Source: American Association of Port Authorities.)

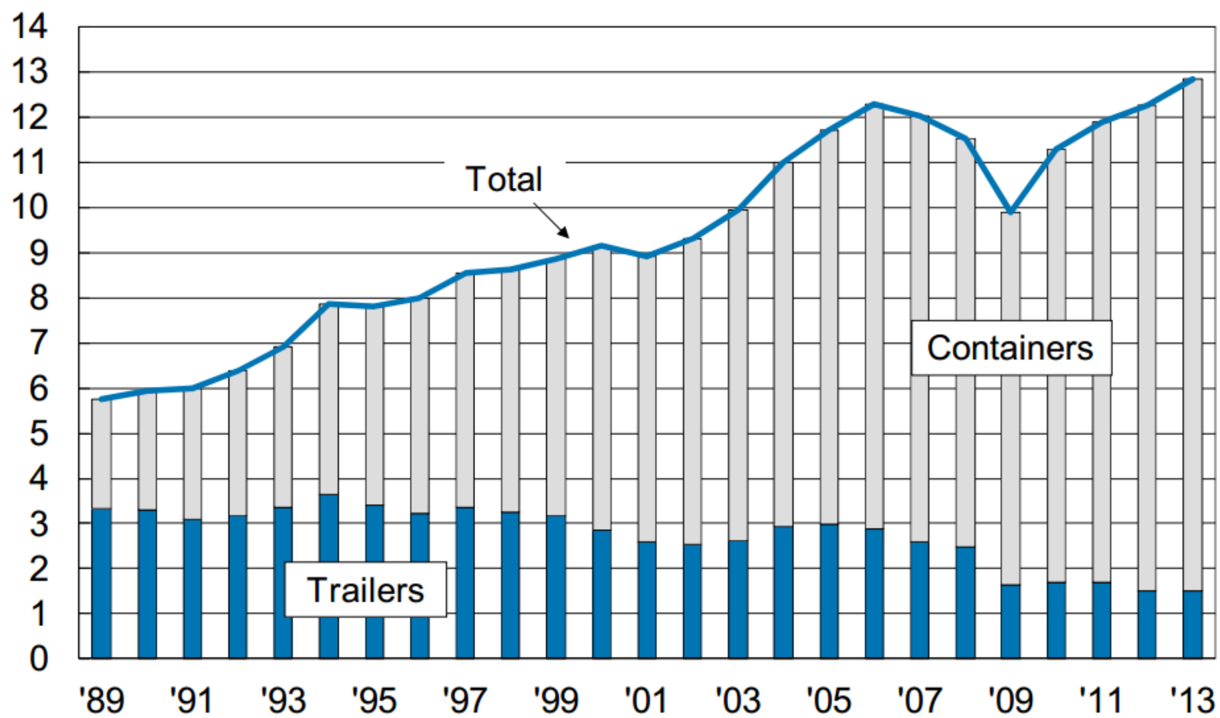

Figure 2. Chart. U.S. Rail Intermodal Traffic, 1989 to 2013—Millions of Containers and Trailers.
(Source: American Association of Railroads.)

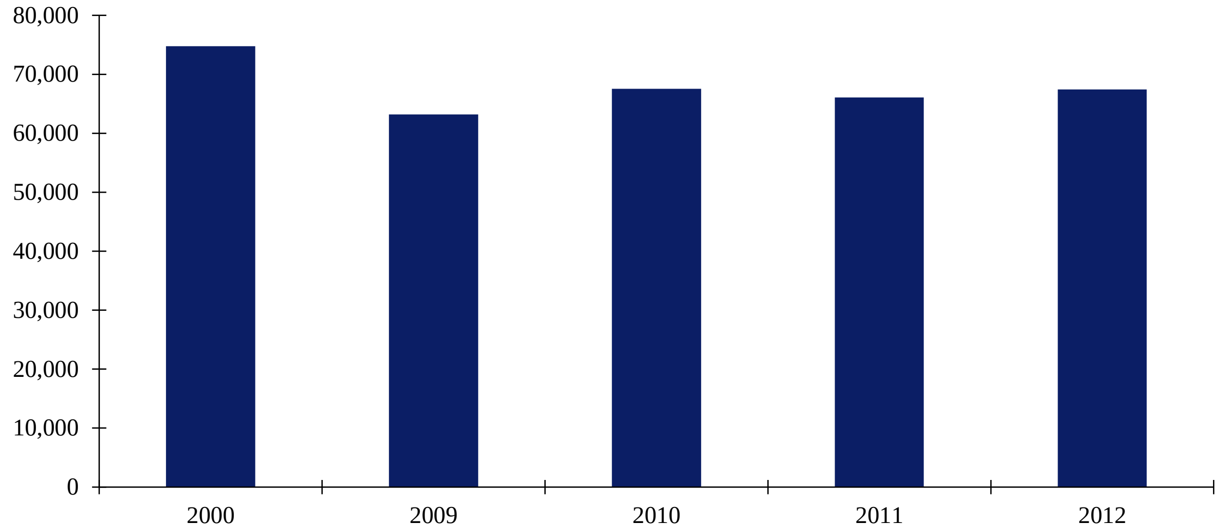

Figure 3. Graph. Landed Weight for All-Cargo, Air Cargo Operations—In Thousands. (Source: Freight Facts and Figures 2013, USDOT Federal Highway Administration and Bureau of Transportation Statistics.)

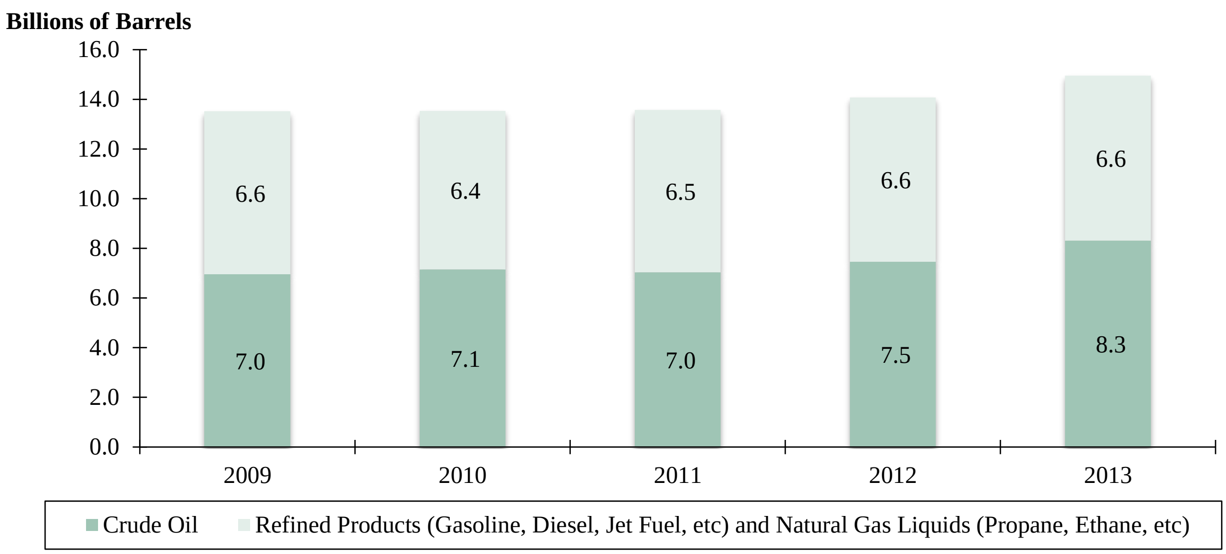

Figure 4. Graph. Liquid Pipeline Transportation in U.S.—2009 to 2013. (Source: U.S. Pipeline and Hazardous Materials Safety Administration, September 2014.)

EMERGING TRUCK-TRUCK TERMINALS AND TRAFFIC VOLUMES

Truck-truck terminals have emerged as a significant new terminal type since the initial NHS freight intermodal connector designation. These facilities include warehouses and distribution centers that are used to deconsolidate, sort, store, classify, and consolidate shipments typically from multiple suppliers to multiple receivers. These facilities also often shift cargo between 20-foot and 40-foot intermodal containers to longer 53-foot-over-the-road domestic trailers for medium and long-haul shipping. Many of these facilities are also located near ports and intermodal rail yards and serve as an extension to larger national and international supply chains.

The growth in these facilities is exemplified by the growth in warehouse employment in the U.S. Table 4 shows warehousing employment in the U.S. rose from 572,000 to 744,500 between 2004 and 2014, an increase of 23 percent. This is particularly noteworthy as many of the newer facilities are highly mechanized and process more shipments per employee than older generation facilities.

Many of the newer truck-truck facilities have been located close to existing industrial areas or co-located with other similar facilities for one or more of several reasons: 1) to be located close to industrial customers, suppliers, and support services; 2) due to constraints based on land use availability and regulations; 3) to take advantage of municipal tax incentives; and 4) to ensure access to an existing workforce trained in needed industrial and warehouse skills. These clusters of industrial and truck-truck facilities have often been termed freight villages.

Table 4. U.S. Warehousing Employment—2004 to August 2014.

Year	**U.S. Warehousing Employment**
2004	572,000
2005	615,900
2006	656,600
2007	675,800
2008	657,400
2009	620,500
2010	641,400
2011	664,100
2012	707,000
2013	725,000
2014 (August)	744,500

(Source: Bureau of Labor Statistics, 1998 data from The Rise of Mega Distribution Centers and the Impact on Logistical Uncertainty; Transportation Letters: The International Journal of Transportation Research, Andreoli, Goodchild, and Vitasek, 2010.)

CHAPTER 3. CONNECTOR CHARACTERISTICS, USE, CONDITION, AND PERFORMANCE

GENERAL CHARACTERISTICS OF FREIGHT INTERMODAL CONNECTORS

The inventory of National Highway System (NHS) freight intermodal connectors is primarily comprised of relatively short connectors. Table 5 shows that the vast majority of the connectors are short in length with 71 percent of the connectors being less than one mile, and 31 percent of the connectors are less than one-quarter of a mile long.

There are very few long connectors, but they make up the majority of the centerline miles of the NHS intermodal connector system. Twelve percent of the freight intermodal connectors are two miles or longer. From a centerline mile perspective, these longest 12 percent of connectors are responsible for nearly half of the total 1,484 miles of freight intermodal connectors in the U.S.

The average length of freight intermodal connectors increases as the roadway functional class increases. Table 6 shows the average length of freight intermodal connectors by functional classification. Local roads are the shortest connectors with an average of 0.45 miles and principal arterials are the longest connectors with an average of 1.51 miles.

Two-thirds of freight intermodal connectors are owned by city, county, or other local agencies with the other one-third owned by State agencies (Table 7). In total, 91 percent of local roads are owned by local agencies; 84 percent of collectors are owned by local agencies; and arterials are split roughly evenly between local and State agencies.

Combining the finding of Tables 5 to 7 together, it indicates that NHS freight intermodal connectors can be generalized by falling into two categories:

1. A large number of short, local roads and minor collectors that are owned by city and local municipalities.

2. A small number of longer arterials that are owned by State agencies.

Table 5. Distribution of Segment Lengths for Freight Intermodal Connectors.

Length (Miles)	Number of Connectors	Percent of Total
0 to 0.25	467	30.9%
0.26 to 0.99	613	40.5%
1.00 to 1.99	245	16.2%
2.00 to 2.99	92	6.1%
3.00 to 3.99	40	2.6%
4.00 to 4.99	20	1.3%
5.00 to 5.99	15	1.0%
6.00 to 6.99	6	0.4%
7.00 to 7.99	5	0.3%
8.00 to 8.99	2	0.1%
9.00 to 9.99	0	0.0%
10 and more	8	0.5%
All	**1,513**	**100.0%**

(Source: 2013 Federal Highway Administration Highway Performance Monitoring System.)

Table 6. Average Length of Connectors by Functional Classification.

Functional Classification	Average Length	Number of Connectors
Local	0.42	202
Minor Collector	0.56	7
Major Collector	0.70	386
Minor Arterial	0.99	558
Principal Arterial	1.51	356
Interstate	0.39	2
Unclassified	0.23	2
All	**0.98**	**1,513**

(Source: 2013 Federal Highway Administration Highway Performance Monitoring System.)

Table 7. Number of Connectors by Owner and Functional System Code.

Owner	Average Length	Local	Minor Collector	Major Collector	Minor Arterial	Principal Arterial (Other Freeways and Expressways)	Principal Arterial (other)	Interstate	Unclassified	Total	Percent of Total
City or Municipal Highway Agency	0.68	121	1	251	320	3	125	—	1	822	54%
State Highway Agency	1.66	18	4	63	172	29	149	2	1	438	29%
County Highway Agency	0.94	17	2	56	48	—	37	—	—	160	11%
Other Public Instrumentality	0.47	38	—	—	2	—	3	—	—	43	3%
Town or Township Highway Agency	0.61	3	—	14	15	—	5	—	—	37	2%
Other Local Agency	0.65	5	—	2	—	—	4	—	—	11	1%
Other State Agency	1.19	—	—	—	1	—	—	—	—	1	<1%
State Toll Authority	0.62	—	—	—	—	—	1	—	—	1	<1%
Total	**0.98**	**202**	**7**	**386**	**558**	**32**	**324**	**2**	**2**	**1,513**	**100%**
Percent of Total		13%	0%	26%	37%	2%	21%	0%	0%	100%	

(Source: 2013 Federal Highway Administration Highway Performance Monitoring System.)

FREIGHT INTERMODAL CONNECTOR TRUCK VOLUMES

Truck volumes on freight intermodal connectors range from a few trucks per day to well over 1,000 per day. The Federal Highway Administration (FHWA) maintains the Highway Performance Monitoring System (HPMS) database as a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways. Using FHWA HPMS data, it is estimated that the average truck volume on freight intermodal connectors is 762 trucks per day. Half of all of connectors have less than 500 trucks per day. Seventy-five percent of connectors have less than 1,000 trucks per day.

In total, it is estimated that there were 1,368,219 truck miles traveled on freight intermodal connectors in 2013. There are a small number of intermodal connector roads that carry the majority of the intermodal truck vehicle miles travelled (VMT), the amount of mileage traveled by trucks on the nation's roadways. Nearly half of all of the intermodal truck VMT occurs in the top 5 percent of freight intermodal connectors in terms of volume. Ninety-seven percent of the truck VMT is captured on the top 50 percent of connectors.

State highway agencies are the owners of just 29 percent of freight intermodal connectors, but they carry 59 percent of the total connector truck VMT. The reverse is true for city or municipal highway agencies. They own 54 percent of intermodal connectors, however carry just 29 percent of connector truck VMT. The vast majority (88 percent) of connector truck VMT occurs in urbanized areas.

The truck volume numbers combined with the centerline mileage data indicate that there is a tradeoff between allocating resources to the smaller number of freight intermodal connectors with large truck VMT (more likely to be longer, State-owned arterials) versus allocating resources to the large number of very short connectors with small truck VMT (more likely to be shorter, locally owned roads).

Truck Volume Data Accuracy

The FHWA HPMS is the most comprehensive source of truck volume data on freight intermodal connectors. HPMS data can be used to examine trends in truck activity relative to other factors such as roadway characteristics and freight facility types. However, for planning studies focused on an individual freight intermodal connector, the accuracy of the HPMS is often not sufficient. The limitations of the HPMS are understandable, because the database is not intended to be utilized as a source for truck activity data on local roads with relatively low volumes.

The truck volume accuracy issue on freight intermodal connectors is primarily due to the HPMS process that is used to estimate truck volumes. This process allows for the use of truck percentage estimates for many locations, often through the use of truck percentages at nearby locations or roadways with similar functional classification. The HPMS process is appropriate to develop system level estimates of truck activity across various roadway functional classifications. However, because truck percentages on freight intermodal connectors tend to be higher than these proxy roads, this process tends to underestimate the number of trucks on the connectors.

Truck accuracy issues are most evident in examining the percentage of single unit and combination trucks on freight intermodal connectors. On most of the freight intermodal connectors, the HPMS reports the number of single unit trucks as higher than combination trucks. This is in contrast to the prevalence of combination trucks being used to access the freight facilities that are being accessed by trucks using freight intermodal connectors. The high percentage of single unit trucks on freight intermodal connectors is likely a function of the use of nearby and similar roadways to estimate single unit and combination trucks rather than the use of actual roadways. One potential improvement to the HPMS would be to utilize a unique factor for estimating single unit and combination trucks for freight intermodal connectors that is not based on factors that are used in other types of locations.

The challenges associated with using the HPMS database for freight intermodal connectors are well known by many freight facility planners. Transportation agencies generally collect new truck count data for planning studies focused on individual freight intermodal connectors.

Truck volume data is critical to estimating truck performance such as crash rates and impacts of congestion and pavement condition. Additionally, truck volume data are critical to determining the benefits of improvements and developing project prioritization related to improvements of freight intermodal connectors. Therefore, improving truck volume data is the single most important data improvement that needs to occur in terms of understanding the role, performance, and potential of the Nation's freight intermodal connectors.

PAVEMENT CONDITION OF FREIGHT INTERMODAL CONNECTORS

State Departments of Transportation (DOTs) submit pavement condition data into the HPMS database in the form of International Roughness Index (IRI) values. The IRI measures the smoothness of the roadway using an algorithm based on the longitudinal profile of a section of the road.[6] Lower IRI values indicate better pavement conditions (i.e., smoother) while higher values indicate worse conditions (i.e., rougher). Table 8 shows the condition categories for IRI measurements based on the FHWA Conditions and Performance Report.

Of the 1,239 connectors with available pavement data in the HPMS, 438 (37 percent) are rated as poor and 236 (19 percent) are rated as mediocre. Only 15 percent of the connectors have a good or very good pavement conditions.

Average IRI values for connectors owned by State highway agencies is 154 (fair) compared to an average value of 257 (poor) for city or municipal highway agencies. Additionally, average IRI values tend to decrease as the length of connectors increases (Table 9). Combined with earlier findings, this reveals that there are two primary types of connectors:

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[6] Federal Highway Administration (2013). Chapter 3—System Conditions, *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report.*

1. Short, low-volume connectors owned by cities or municipal agencies with poor pavement condition; and

2. Relatively long, high-volume connectors owned by State highway agencies with fair pavement condition.

Table 8. International Roughness Index Categories.

Pavement Condition Categories	**International Roughness Index Rating (inches/mile)**	**Pavement Condition Description**	**Number of Connectors**	**Percent of Total**
Very Good	<60	Newly built or resurfaced and distress-free.	14	1%
Good	60-94	Smooth surface with little to no cracking or rutting.	103	8%
Fair	95-170	Serviceable with shallow rutting and moderate cracks beginning to occur, but does not affect travel speed on the connector.	428	35%
Mediocre	171-220	Same problems as fair but worse, causing some reduction in speed.	236	19%
Poor	>220	Major problems with potholes, etc., causing substantial reductions in speed.	458	37%
Total			**1,239**	**100%**

Table 9. Average International Roughness Index Rating by Length of Connector.

Length (miles)	**Number of Connectors**	**Average IRI**
0 to 0.99	862	233
1.00 to 1.99	208	179
2.00 to 2.99	84	153
3.00 to 3.99	32	134
4.00 to 4.99	18	138
5.00 to 5.99	14	111
6.00 to 6.99	6	95
7.00 to 7.99	5	114
8.00 to 8.99	2	93
9.00 to 9.99	0	N/A
10 and more	8	96
All	**1,239**	**211**

National Performance Goals and Connector Pavement Conditions

The U.S. Department of Transportation (USDOT) set a national performance goals for 2013 of having 57 percent of vehicle miles traveled (VMT) on the entire National Highway System to be on pavements with good ride quality. As noted in the 2015 American Association of State Highway and Transportation Officials (AASHTO) Transportation Bottom Line Report, States and other owners of the road system have increasingly focused their resources on improving the road systems that are used most extensively by passengers and goods movement. As a result, the percentage of VMT on roads identified as in good condition improved between 2000 and 2010, even while the length of roads in good condition has declined from 43 percent to 35 percent.

This trend in roadway maintenance has been detrimental for the quality of freight intermodal connectors. As the connectors often have lower total vehicle volumes relative to similarly classified roadways, they also tend to fare worse in VMT-based performance metrics.

Freight intermodal connectors are more likely to approach poor condition faster than other roadways because of their high truck percentage. The 57 percent VMT goal makes it more challenging for connectors that fall into poor condition to compete for funding, because the cost to improve a roadway from poor to good condition far exceeds the cost to improve a roadway from fair to good.

State Departments of Transportation can more cost-effectively reach the 57 percent VMT goal by improving fair roads with high volumes to good condition than they can by improving freight intermodal connectors with lower volumes from poor to good condition. Additions to the national performance goals that could lead to greater improvement in roadway conditions for freight intermodal connectors include the following:

- A goal to limit the maximum percentage of roadways in poor condition.
- Adjustment of the 57 percent goal to be based on passenger car equivalent VMT rather than total VMT.
- Specific goals for pavement condition of freight intermodal connectors in each State.

SPEEDS ON FREIGHT INTERMODAL CONNECTORS

This section assesses the performance of intermodal connectors using average truck speed data available in the FHWA National Performance Monitoring Research Data Set (NPMRDS). Speeds were extracted from the database using April 2014 data for all intermodal connectors. Speeds were calculated for the following four periods:

1. Morning hour – 8:00 a.m. to 9:00 a.m.
2. Midday hour – 12:00 p.m. to 1:00 p.m.
3. Afternoon hour – 5:00 p.m. to 6:00 p.m.
4. Late night period – 12:00 a.m. to 3:00 a.m.

The late night period is assumed to represent free-flow speeds for the intermodal connectors. Speed differentials between the late night speeds and speeds from the other three periods are assumed to be based on some type of truck bottleneck.

Table 10 shows the average truck speeds for urban and rural designated roadways for each time period. The average speeds during the morning, midday, and afternoon time periods for urban roads are the same at 25 miles per hour (mi/h). Similarly, for rural roads, average speeds for the morning and midday time periods are 37 mi/h with the afternoon time period average speed only slightly faster at 38 mi/h. During the late night time period (midnight to 3:00 a.m.), the average rural speed is 42 mi/h, 50 percent faster than 28 mi/h average speeds on urban roads. The speeds also are 50 percent higher on rural roads relative to urban roads for the other three time periods. The difference between late night speeds and daytime speeds is just over 10 percent for both urban and rural locations.

There appears to be a relationship between pavement condition and truck travel speeds. Table 11 highlights average truck travel speeds by pavement condition and time of day. During the late night time period between 12:00 a.m. and 3:00 a.m. (which is assumed to be free-flow conditions), the speeds on poor pavement is 23 mi/hr. compared to speeds of 27 mi/hr., 31 mi/hr., and 32 mi/hr. for mediocre, fair and good pavement condition respectively. Similarly, speeds during other times of day are generally slower for pavement that is of worse condition.

There is no demonstrated relationship between pavement quality and congestion. The decrease from free-flow speeds to peak-period speeds falls within a range of 10 to 16 percent, but there is no trend in terms of this decrease relative to pavement condition.

Table 10. Average Speeds of Intermodal Connectors by Rural/Urban Designation (miles per hour).

Urban Functional System Code	**Number of Connectors**	**Time Period (8:00 to 9:00 a.m.)**	**Time Period (12:00 to 1:00 p.m.)**	**Time Period (5:00 to 6:00 p.m.)**	**Time Period (12:00 to 3:00 a.m.)**	**Difference Between Late Night and Slowest Day Speed**
Urban	1,380	25	25	25	28	-11%
Rural	123	37	37	38	42	-12%

(Source: 2014 National Performance Management Research Data Set.)

Table 11. Average Speeds of Intermodal Connectors by Pavement Condition (miles per hour).

International Roughness Index (IRI) Category	Number of Connectors	Time Period (8:00 to 9:00 a.m.)	Time Period (12:00 to 1:00 p.m.)	Time Period (5:00 to 6:00 p.m.)	Time Period (12:00 to 3:00 a.m.)	Difference Between Late Night and Slowest Day Speed
Poor	354	20	21	21	23	-13%
Mediocre	221	24	24	23	27	-15%
Fair	469	28	28	28	31	-10%
Good	118	27	28	29	32	-16%
Very Good	38	28	26	27	29	-10%

(Source: 2014 National Performance Management Research Data Set data.)

Total delay experienced on freight intermodal connectors was estimated based on the speed data in Table 10. Total urban and rural VMT was estimated based on multiplying truck volumes by connector lengths using the HPMS data. Hourly distribution for urban and rural roads was extracted from available truck count data.[7,8] The speeds in Table 11 were expanded to represent periods of the day rather than single hours. Based on this analysis, it is estimated that there were 4,237 hours of truck delay every weekday on freight intermodal connectors. This equates to roughly 1,059,238 hours of truck delay annually on freight intermodal connectors. Using the percentages of truck Annual Average Daily Traffic (AADT) relative to total AADT, it is estimated that the total annual auto delay on freight intermodal connectors is 12,181,234 hours.

FREIGHT INTERMODAL CONNECTOR PERFORMANCE MEASUREMENT

The performance of freight intermodal connectors can be measured by using inputs across a number of data elements including speed, travel time, travel time reliability, safety, and cost. This data can be tracked over a period of time to understand if and how the performance of a connector is changing and the rate of change in performance. Additionally, these data can be used to understand how freight improvement projects have changed the performance of a connector's ability to move goods. The performance measures can also be tied to the cost of supply chains to determine the impact of performance on overall cost of goods, cost of doing business, and the competitive position of one terminal relative to others.

There are currently few freight performance measures that are tracked on a regular basis by State DOTs or metropolitan planning organizations (MPOs). FHWA recently started tracking a Freight Efficiency Index as part of the Freight Performance Measures program. The Freight Efficiency Index includes four categories: 1) intermodal; 2) truck bottlenecks; 3) border crossings; and 4) urban mobility, along with an aggregate measure of freight performance. The intermodal component of the index is based on the following features:

[7] Texas Department of Transportation, Developing Freight Highway Corridor Performance Measure Strategies in Texas, 2006.

[8] Hampton Roads Planning District Commission, Hampton Roads Intermodal Management System.

- Approximately 43 miles of intermodal roadways (container ports and intermodal rail facilities) are included in this measure; more than one-half of these roadways are Functional Class Principal Arterial or above with design speeds at 35 miles per hour or higher.

- Geographic Information Systems (GIS) and statistical algorithms are used to select data for the highway segments at each location for the corresponding quarter.

- Average speeds are placed in a table and the key indicator is an average speed representing all locations. A quarterly measurement is developed based on the average of the average speeds at 30 facilities.

An example of the freight intermodal measure for the fourth quarter of Fiscal Year (FY) 2014 is shown in Figure 5. This graphic shows the current reading, along with the best, worst, and average readings over the last three years. The connectors measured in this index do not match with the designated NHS freight intermodal connectors, but are generally a select sample of these roadways.

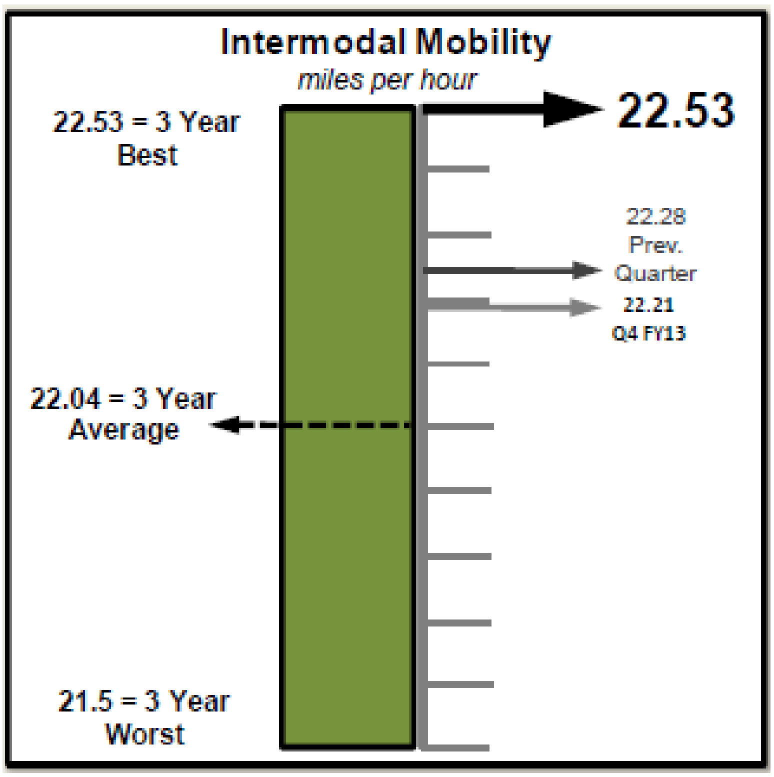

Figure 5. Graph. Intermodal Component of Federal Highway Administration Freight Efficiency Index.
(Source: Federal Highway Administration Quarterly Report of Freight Efficiency Index, Fourth Quarter 2014.)

CHAPTER 4. CASE STUDIES

The objective of the Federal Highway Administration (FHWA) Intermodal Connectors Study is to provide a comprehensive understanding of the condition and performance of the Nation's freight intermodal connectors. The case studies were conducted in conjunction with the Maritime Administration. Therefore, case study locations include more port case studies relative to the other freight modes.

Three emerging industries were included as case studies to focus on how connectors respond to changes in economic activity and supply chains. The emerging industries covered the emergence of oil and gas extraction in Williston in North Dakota; the truck-truck terminal facility in the City of Industry in southern California; and the potential for the use of natural gas as a transport fuel in Jacksonville, Florida.

The specific case studies are listed in Table 12.

Table 12. Case Study Locations.

Ports	Rail	Air Cargo	Emerging Industries
• Port of Baltimore (Maryland) • Port of Philadelphia (Pennsylvania) • Port of Long Beach (California) • Port of Savannah (Georgia) • Port of Catoosa (Oklahoma) • Port of Houston (Texas) • Port of Cleveland (Ohio) • Port of Portland (Oregon)	• Atlanta Inman Yard (Georgia) • Edgerton Yard (Kansas) • Marion Yard (Ohio) • Chicago Area Consolidated Hub (Illinois)	• Memphis (Tennessee) • Portland (Oregon) • Charlotte/Douglas (North Carolina)	• Williston (North Dakota) • City of Industry (California) • Port of Jacksonville (Florida)

METHODOLOGY

The case study methodology included three primary components:

1. Assembling existing data on the use condition and performance of the corridors.

2. Reviewing previous freight-related planning documents.

3. Outreach to freight stakeholders.

The FHWA Highway Performance Monitoring System (HPMS) database and National Performance Management Research Data Set (NPMRDS) were reviewed for each case study connector. HPMS provided data on traffic volumes (truck and passenger), pavement conditions, and functional classification. NPMRDS provided data on truck travel times along some network links from which average truck speeds were derived.

At the State and local levels, information was gathered from long- and short-range planning documents. This included reviewing plans developed by State Departments of Transportation (DOTs), county or city county transportation departments, and metropolitan planning organizations, where applicable. The standard types of documents that were examined included long-range transportation plans (LRTP), congestion management plans (CMP), transportation improvement programs (TIP), and freight plans. Additional documents that were examined included corridor studies, sub-area studies, and freight facility studies. All of these documents were used to understand a connector's current and future conditions (including level of service), planned improvements, and to provide information on how stakeholders convene to conduct freight-related planning.

Stakeholder outreach was used to confirm data sources identified by the consultant team, and determine if there are other data sources or reports that need to be reviewed. Outreach was also used to determine how freight planning related to the connectors was conducted. This included identifying freight champions, describing forums and venues that were used to gain consensus, identifying relevant neighborhood communities, and determining funding mechanisms that are available that can be directed towards freight intermodal connectors. The stakeholders contacted as part of this process were typically DOT and metropolitan planning organization (MPO) freight planners along with freight facility operators and economic development agencies, where appropriate.

CONNECTOR CHARACTERISTICS

Across the 18 case study terminals, 61 roadways were incorporated into the case study process. Most of these roadways are officially designated National Highway System (NHS) freight intermodal connectors. Other roadways are used as connectors, but not officially designated as part of the NHS.

Of the 61 intermodal connectors examined in the case studies, approximately 70 percent are official NHS connectors. Most of the connectors are classified as either Principal or Minor Arterials. Several of them have multiple functional classifications across their extent. Often, these are combinations or Major Collector/Local Road and Minor Arterial/Major Collector. On average, the case study connectors have a somewhat higher functional classification relative to the total population of freight intermodal connectors as described in Chapter 3.

The vast majority of freight intermodal connectors studied have between two and four lanes. Sixteen of the 61 (26 percent) connectors consist of two lanes across their entire length. Another 15 of the connectors ranged from two to four lanes, while 12 of the connectors were comprised of four lanes. Only six of the connectors had six or more lanes. Twelve of the connectors had no information available on the number of lanes, primarily due to non-inclusion in the HPMS database.

CONNECTOR TRUCK VOLUMES

HPMS has good coverage of traffic volume data on the case study intermodal connectors. The database contains information on approximately 78 percent of the 61 case study connectors (Table 13). All of the designated NHS freight intermodal connectors included in the case studies are covered in the HPMS data base. The HPMS did not cover any of the non-designated connectors that were included in the HPMS database. Therefore, one of the benefits of a roadway being designated as a freight intermodal connector is that the roadway then becomes included in the HPMS database resulting in truck and auto volume data being collected on the roadway.

Figures 6 and 7 show the distribution of Annual Average Daily Traffic (AADT) and Average Annual Daily Truck Traffic (AADTT) respectively. The AADTT on the case study intermodal connectors is 1,590 trucks per day with a range from 12 to 3,050 trucks per day. The case study connector truck volumes data tended to have large volumes of single unit trucks relative to combination trucks and this common database error is explained in Chapter 3.

Table 13 also shows there is some differential between average truck volumes on case study connectors based on freight mode. Intermodal connectors serving airports have higher truck volumes than those serving any other freight facilities. This may be due to the dual impact of air cargo operations and trucks needed throughout the day to supply airplanes and airport concession operators. Port and rail intermodal connectors are next highest in terms of truck volumes.

The 14 non-NHS designated intermodal connectors examined in the case studies exhibited even higher AADTT values than the NHS designated connectors. The case studies demonstrated that these roadways often reflect the changing conditions of the freight terminals they serve. As rail traffic shifts to other rail yards, truck gates are expanded or new gates constructed at seaports, and capacity is increased at rail and marine intermodal container terminals, area truck traffic patterns also change. The non-NHS designated connectors are often indicative of these current conditions.

Table 13. Summary of Connector Traffic Volume Data.

Connector Traffic Volume Data Type	Value
Data Availability in Highway Performance Management System (HPMS)	78%
Average of Annual Average Daily Traffic (AADT)	12,516
Truck AADT Data Availability in HPMS	72%
AADT Range	531 to 41,519
Average Truck AADT—All	1,590
Truck AADT Range	12 to 3,050
Average Truck AADT—Airport Connectors	1,758
Average Truck AADT—Port Connectors	1,298
Average Truck AADT—Rail Connectors	1,011
Average Truck AADT—Others	2,606

(Source: Federal Highway Administration Highway Performance Monitoring System database.)

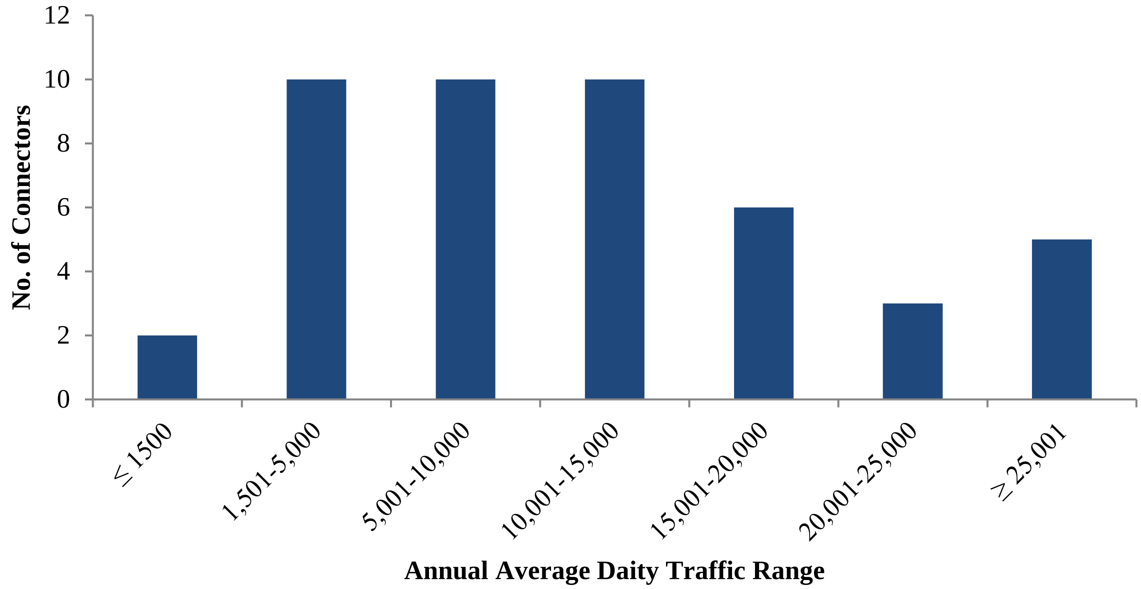

Figure 6. Graph. Distribution of Intermodal Connector Annual Average Daily Traffic—2013. (Source: Federal Highway Administration Highway Performance Monitoring System database.)

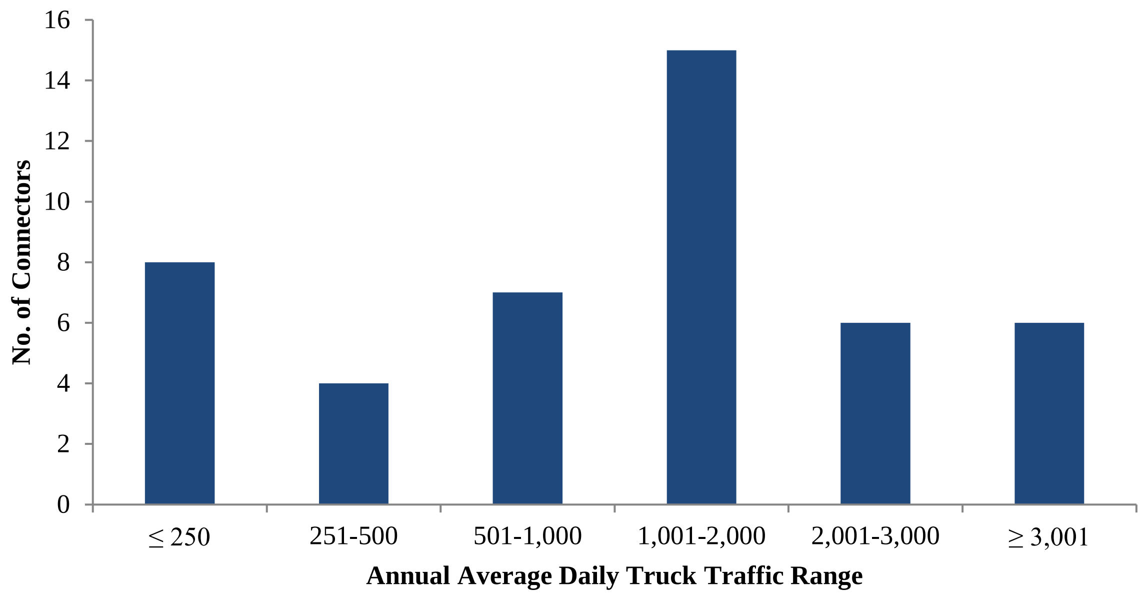

Figure 7. Graph. Distribution of Intermodal Truck Annual Average Daily Traffic—2013. (Source: Federal Highway Administration Highway Performance Monitoring System database.)

CONNECTOR PAVEMENT CONDITION

Pavement condition data are available on 47 of the 61 (75 percent) of the case study connectors. For the 47 designated NHS connectors, the HPMS pavement data are available on 40 (85 percent) of the connectors. For the 14 non-designated connectors, HPMS pavement data are available on only one of the connectors.

Table 14 shows that the average International Roughness Index (IRI) values of the case study intermodal connectors is 196 which rates as “mediocre”. One-third of the connectors rate as being in “poor” condition. Only five percent of the connectors are rated as “good” or “very good”. This distribution is similar to the pavement conditions for all connectors.

Table 14. International Roughness Index Ranges and Categories.

Condition Term Categories	International Roughness Index Rating (inches/mile)	Number of Case Study Connectors in Each Category	Case Study Connector Percent of Total	All Connectors Percent of Total
Very Good	< 60	0	0%	1%
Good	60-94	2	5%	8%
Fair	95-170	18	44%	35%
Mediocre	171-220	7	17%	19%
Poor	>220	14	34%	37%
Total		**41**	**100%**	**100%**

(Source: Federal Highway Administration (2013). Chapter 3—System Conditions, Status of the Nation’s Highways, Bridges, and Transit: Conditions and Performance Report.)

The pavement ratings of each of the case study connectors were compared to the pavement ratings of other roadways in their respective States within similar functional classifications. Table 15 shows that 78 percent of the case study intermodal connectors have higher IRI values (worse pavement conditions) relative to roadways in their States with similar functional classifications. This implies that the vast majority of the connectors are not as well maintained as similar roadways. This may be due to longer maintenance cycles applied to connectors. Alternatively, this may be the result of higher truck volumes on the connectors. This would cause excessive pavement damage which would require increased maintenance to achieve similar pavement quality as what is experienced on non-connector roads.

On average, the IRI rating for the case study connectors was 55 percent higher than similarly classed roadways in their respective States. The average IRI rating for similarly classed roads to the connectors in their States was 128. This indicates that the difference in pavement quality is significantly worse for connectors relative to similar roads. The rougher pavements of freight intermodal connectors likely contributes to higher vehicle maintenance costs and also to loss and damage of the goods being transported. Additionally, it is possible that the freight intermodal connectors received less attention from transportation agencies relative to other roadways.

In conducting the case studies, references to pavement issues were relatively rare. Only one stakeholder mentioned this being a significant driver of an improvement project. The Georgia Ports Authority (which owns and operates the Port of Savannah) informally identified the Chatham County pavement conditions on Grange Road as an impediment to cost-efficient freight mobility. This spurred a resurfacing project to improve conditions on Grange Road. The only formal pavement analysis of intermodal connectors identified in the case study research was conducted in the Chicago metropolitan area as part of the development of the region’s truck route network.

Table 16 shows the IRI pavement ratings for case study connectors by terminal mode. This table shows that freight rail intermodal connectors have the best pavement conditions with an average IRI rating of 107. This rating qualifies as “Fair,” but it is very close to being rated as “Good” pavement condition. Air cargo intermodal connectors have the second best pavement condition with an average IRI rating of 168. These modal connectors also are rated as “Fair,” but they are very close to being rated as “Mediocre.” The port intermodal connectors have the worst pavement conditions of all of the roadways with a rating of 230 which qualifies the condition as “Poor.”

Table 15. Comparison of Case Study Connectors and Other Roadways with Same Roadway Functional Classification—2013.

Characteristic	**Value**
Availability of Case Study Connector Data in Highway Performance Monitoring System	67%
Average IRI Rating for Case Study Connectors	196
Average IRI Rating for Roadways with Similar Functional Classification in the State	128
Percent of Connectors with Higher (Worse) Rating than Similar Functional Classification in the Same State	78%
Average Difference Compared to State Average for Similar Functional Classification	55%

(Source: Federal Highway Administration Highway Performance Monitoring System database.)

Table 16. Connector Pavement Rating by Mode—2013.

Connector Freight Mode	**Average International Roughness Index (IRI) Rating**	**IRI Category**
Rail	107	Fair
Air Cargo	168	Fair
Port	230	Poor

(Source: Federal Highway Administration Highway Performance Monitoring System database.)

CONNECTOR TRUCK TRAVEL SPEEDS AND CONGESTION

Truck travel speeds on the case study connectors were examined for the month of April 2014 between the periods of 8:00 to 9:00 a.m., 12:00 to 1:00 a.m., 5:00 to 6:00 a.m., and Midnight to 1:00 a.m. These time periods are directly comparable to those used for the analysis of all of the connectors described in chapter 3.

The availability of truck travel speed data on the case study connectors is provided in Table 17. Fifty-two percent of the connectors have data available for the travel speed analysis. Seventy-one percent of designated NHS case study connectors had truck travel speed available, while 24 percent of the non-designated case study connectors had truck travel speed available.

Table 18 shows the average truck speeds by time of day and mode for the case study connectors. The highest average speed is 31 mi/h on rail intermodal connectors during the nighttime period. The rail mode also experienced the most congested periods with a morning period that featured average speeds 35 percent below the nighttime period. Airport connectors had the lowest average nighttime speeds at 26 mph, but had daytime congestion that reduced speeds no more than 11 percent.

Port and rail intermodal connectors were found to have the most often congested corridors, with 75 percent of their corridors having daytime speeds that were less than 90 percent of free-flow speeds. Only 38 percent of the airport intermodal connectors were found to be congested during daytime hours. The lower congestion for airport intermodal connectors may be due to the dual role of these connectors as serving both passengers and goods movement, and therefore having more opportunities to be considered for transportation improvements. The higher number of non-freight trips on airport intermodal connectors also resulted in a lower percentage of the total congestion on these roads being absorbed by truck trips.

Table 17. Percent of Case Study Connectors with Congestion by Mode.

Connector Truck Speed Data	Value
Data Availability in National Performance Management Research Data Set (NPMRDS)	52%
Connectors with Daytime Congestion—All	68%
Connectors with Daytime Congestion—Rail	75%
Connectors with Daytime Congestion—Port	75%
Connectors with Daytime Congestion—Airport	38%
Connectors with Daytime Congestion—Others	100%

(Source: Federal Highway Administration National Performance Management Research Data Set.)

Table 18. Average Truck Speeds by Facility Type and Time Period—April 2014.

Facility Type	8:00 to 9:00 a.m.	12:00 to 1:00 p.m.	5:00 to 6:00 p.m.	Midnight to 1:00 a.m.	Difference between Free-Flow Speeds and Most Congested Period
Airport	25	23	24	26	-11%
Port	21	20	20	27	-28%
Rail Terminal	20	22	21	31	-35%
All Freight Facilities	22	21	20	27	-26%

(Source: Federal Highway Administration National Performance Management Research Data Set.)

GOVERNANCE AND STAKEHOLDER COORDINATION

There was no pattern in the ownership of intermodal connectors included in the case studies. In fact, it was not uncommon for a single connector to have multiple owners as many extend across county and municipal boundaries. Intermodal connectors serving the Port of Savannah are a good example of this observation. Portions of the intermodal connectors lie in the City of Savannah, City of Pooler, City of Port Wentworth, Garden City, and unincorporated Chatham County in Georgia. Maintenance of these roadways is divided between the Georgia Department of Transportation, Chatham County, and city governments. The presence of so many government entities makes stakeholder coordination and leadership from freight champions critical for successful planning related to intermodal connectors. This is especially true considering that formal freight planning processes are still evolving at most transportation agencies.

The impetus to plan for freight intermodal connectors generally arose from one of two sources: 1) State-level concerns about economic development; and 2) community/local concerns regarding high levels of truck and rail traffic near residential neighborhoods. This observation highlights an important challenge faced by intermodal connectors and the freight terminals they serve. They often facilitate economic activity that yields benefits across a wide geographic scale though the negative externalities are borne locally. Though this observation on the freight system has been made before, it was evident in the case studies as well.

The need to balance statewide economic development concerns with community needs is most evident in regards to planning for new intermodal rail yards. Many of the newer intermodal rail yards are built with substantial support from State governments on the basis of that the facilities would make many existing statewide companies more competitive and that the presence of the facility would assist in attracting new freight-dependent companies to the State. Because intermodal rail yards have large footprints and they are ideally located within metropolitan areas (though often on the fringes), there are typically nearby communities that become concerned about the impact of the facility on local roads neighborhoods. This was evident for the case studies for the Marion (Ohio) and Edgerton (Wisconsin) intermodal rail yards.

PLANNING FOR CASE STUDY CONNECTOR LEVEL OF SERVICE

Base-year level of service data on the intermodal connectors is sparse. The connectors located in metropolitan planning organization (MPO) regions were generally included in the MPO's regional travel demand model. However, this was not universally true, especially for smaller roadways. Furthermore, extracting data for these roadways from travel demand models is generally time consuming. Additionally, the accuracy of the model outputs on connectors may not be accurate, because it is rare for models to be calibrated or validated on these types of roadways. The exception to this is the Port of Long Beach, which has a truck trip model that is designed specifically based on current and future flows for each terminal within the port's complex. The Los Angeles region's MPO incorporates the port truck trip model into its wider region-wide travel demand model.

Additionally, it is rare for this level of service information on intermodal connectors to be available from the standard planning documents such as MPO long-range transportation plans, MPO congestion management plans, or statewide long-range transportation plans. Even in regional and statewide freight plans, the level of service on the connectors was rarely incorporated explicitly. These plans typically relied on travel demand models and outreach to determine the performance of connectors. It was most likely for this level of service information to be included on sub-regional studies that had a study area that incorporated the connectors or where truck traffic on connectors was a specific focus area of the study.

In the few cases where level of service information was identifiable from other sources, it did not capture congestion as well as the Federal Highway Administration (FHWA) National Performance Management Research Data Set (NPMRDS) data.

FUTURE CONDITIONS

Information on the future conditions of the intermodal connectors was drawn primarily from travel demand models. Because few models incorporate freight facilities as special generators within their models, the accuracy of projected levels of service on freight intermodal connectors can be an issue. However, these models are useful for determining how background traffic will change over time, so there is still value in reviewing forecast-year outputs from travel demand models on and near freight intermodal connectors.

Future truck volume and congestion conditions on freight intermodal connectors can also be determined using forecast data available through the HPMS. The growth rates of these forecasts tend to be based on aggregate traffic conditions and therefore not reflective of the predicted activity of the freight terminals or surrounding industrial land uses of trucks using freight intermodal connectors.

CONNECTOR IMPROVEMENT PROJECTS

Planned improvements on the case study connectors can typically be found in local MPO Transportation Improvement Programs (TIP) or State DOT Statewide Transportation Improvement Programs (STIP). Many of the connectors had either short- or long-range projects that were targeted for them. The types of improvement projects most often found for the case study connectors address congestion/capacity problems, conflicts with trucks and passenger vehicles, and neighborhood/land use issues.

Pavement issues are not commonly cited as the primary issue supporting an improvement project. There are no cases in which a formal pavement analysis was conducted on any of the case study connectors. However, there are instances of connectors being included in wide scale resurfacing projects. Table 19 lists planned improvement categories and provides examples of the case study facilities that included each type of improvement.

Table 19. Planned Improvements for Intermodal Connectors.

Planned Improvements	Number of Connectors and Examples
Resurfacing	**Some—**Connectors at the Port of Baltimore, Port of Catoosa, Port of Jacksonville, and the Marion Intermodal Terminal are programmed for resurfacing in the Transportation Improvement Programs and Statewide Transportation Improvement Programs cited in the case studies.
Capacity	**Some—**Connectors at the Port of Houston, Port of Jacksonville, Port of Savannah, and the City of Industry's Industrial Complex are programmed for road widening projects.
Signal Upgrades	**Few—**A few agencies are implementing signal upgrades and timing plans on corridors that include some of the intermodal connectors. These include connectors at the Port of Houston and Portland International Airport.
Interchange Construction/ Reconstruction	**Many—**Many States and metropolitan planning organizations are undertaking efforts to construct or reconstruct interchanges between the connectors and major roadways. Connectors at the Port of Catoosa, Port of Jacksonville, Port of Savannah, Charlotte-Douglas International Airport, and Memphis International Airport all have interchange projects listed in their referenced Transportation Improvement Programs and/or Statewide Transportation Improvement Programs.

IDENTIFIED FUNDING PROGRAMS FOR CASE STUDY CONNECTOR IMPROVEMENTS

The National Cooperative Highway Research Program (NCHRP) Report 497, Financing and Improving Land Access to U.S. Intermodal Cargo Hubs, reviewed 13 infrastructure improvement projects for roads accessing intermodal facilities. This review included documenting the sources of funds for making the improvements. Table 20 summarizes the sources of funds across types of agencies. It shows that Federal and State transportation agencies are present in virtually all of the improvement projects. Local transportation agencies were funding partners in a little over half of the projects. Economic development agencies contributed funds to 3 of the studies and direct user fees were utilized in four of the studies. Two projects received funding through the Congestion Mitigation and Air Quality program.

Table 20. Funding Sources for Select Freight Intermodal Connectors.

Funding Source	Number of 13 Projects Funded Through Source
Federal Transportation Agency	12
State Transportation Agency	11
Facility Operator	9
Local Transportation Agency	7
Direct User Fees	4
State Economic Development Agency	3
Bonds	3
Private	2

(Source: National Cooperative Highway Research Program Report 497, Financing and Improving Land Access to U.S. Intermodal Cargo Hubs, 2003.)

The heavy use of State and Federal funding was also evident in the improvements identified in the case studies conducted for this study. This indicates that funding patterns have not changed significantly since the NCHRP study was completed. State transportation agencies tended to take the lead for improvement projects that were heavily focused on economic development. Local transportation agencies tended to take the lead for projects that were more focused on community impacts and mitigation of truck activity. In either case, Federal funding was a primary source of funds for the respective projects.

The Florida Department of Transportation (DOT) is the only State DOT that has specific funded programs targeted towards freight intermodal connectors. As part of the Florida Statewide Intermodal System (SIS), a “Quick Fix” initiative was developed to address operational improvements to connectors. In FY 2013/2014, this program was used to fund portions of seven projects at a cost of just under $7 million. The improvements included auxiliary lanes, exit ramp improvements, adding new lanes, developing turn lanes, and resurfacing an intersection using concrete. In FY 2014/2015, this program was used to fund portions of eight projects at a cost of just over $15 million.

The Florida DOT also funds the Intermodal Access Program, which predates the SIS program, and is used by FDOT districts to implement small-scale connector and terminal projects that do not qualify for funding through the SIS program. The Intermodal Access Program includes access improvements to intermodal facilities, airports, and seaports. These improvements may be targeted towards either freight or passengers. Currently, the Miami Intermodal Center and the Jacksonville Multimodal Terminal Center are partially funded under this program. Between FY 2014 and FY 2019, over $250 million of projects are planned to be partially funded through this program.[9]

[9] Florida Department of Transportation Program and Resource Plan, Fiscal Years 2013/2014 through 2018/2019, April 2014. Florida Department of Transportation Office of Work Program and Budget, Finance, Program and Resource Allocation.

CHAPTER 5. CONNECTOR PERFORMANCE IMPACTS ON GOODS MOVEMENT AND SUPPLY CHAINS

IMPACT OF PAVEMENT MAINTENANCE COSTS

One of the impacts of substandard pavement condition on traveling is an increase in vehicle wear and tear. This in turn increases vehicle maintenance and repair costs, which are a component of vehicle operating costs. The Federal Highway Administration (FHWA) Highway Economic Requirements System (HERS) was used to estimate the cost to improve all of the freight intermodal connectors to good condition based on their current pavement condition, functional classification, and area type.

The cost estimate for improving the pavement condition on all designated National Highway System (NHS) freight intermodal connectors to "Good" is approximately $2.2 billion (Table 21). The vast majority of these costs (78 percent) are for improvements targeted towards urban arterials. Table 22 shows the costs to improve connectors to good pavement condition by mode. It shows that nearly half of the costs for improvements needs to be focused on port intermodal connectors.

Table 21. Cost to Improve Connectors to Good Pavement Condition.

Area Type	Roadway Functional Classification	Before and After IRI Ratings	Number of Lane Miles	Cost to Improve per Lane Mile[1]	Total Cost to Improve ($ Millions)
Rural	Principal Arterial	Fair to Good	82	220,000	18,070,800
Rural	Principal Arterial	Mediocre to Good	6	419,000	2,514,000
Rural	Principal Arterial	Poor to Good	4	618,000	2,472,000
Rural	Minor Arterial	Fair to Good	40	195,000	7,790,250
Rural	Minor Arterial	Mediocre to Good	26	369,000	9,582,930
Rural	Minor Arterial	Poor to Good	0	543,000	—
Rural	Collector/Local	Fair to Good	103	199,000	20,574,610
Rural	Collector/Local	Mediocre to Good	17	387,000	6,439,680
Rural	Collector/Local	Poor to Good	4	575,000	2,127,500
Urban	Principal Arterial	Fair to Good	711	424,750	301,844,340
Urban	Principal Arterial	Mediocre to Good	365	1,156,625	421,728,608
Urban	Principal Arterial	Poor to Good	124	1,888,500	233,380,830
Urban	Minor Arterial	Fair to Good	667	300,000	200,028,000
Urban	Minor Arterial	Mediocre to Good	254	813,500	206,222,250
Urban	Minor Arterial	Poor to Good	264	1,327,000	350,964,960

Table 21. Cost to Improve Connectors to Good Pavement Condition (continuation).

Area Type	Roadway Functional Classification	Before and After International Roughness Index (IRI) Ratings	Number of Lane Miles	Cost to Improve per Lane Mile	Total Cost to Improve ($ Millions)
Urban	Collector/Local	Fair to Good	173	300,000	51,957,000
Urban	Collector/Local	Mediocre to Good	110	813,500	89,842,940
Urban	Collector/Local	Poor to Good	201	1,327,000	266,408,520
ALL	**ALL**	**ALL**	**3,150**	**—**	**2,191,949,218**

(Source: Federal Highway Administration Highway Performance Monitoring System, 2013)

Table 22. Cost to Improve Connectors to Good Pavement Condition by Mode.

Area Type	Total Cost to Improve ($ Millions)	Percent of Total
Port	1,061,023,573	48%
Rail	599,430,960	27%
Air Cargo	389,708,887	18%
Pipeline	141,785,798	6%
ALL	**2,191,949,218**	**100%**

(Source: Federal Highway Administration Highway Performance Monitoring System, 2013)

IMPACT ON VEHICLE OPERATING COSTS

Pavement conditions on designated freight intermodal connectors also impact vehicle operating costs for both trucks and autos that use those roadways. Research on the relationship between vehicle operating costs and pavement conditions has developed a wide range of estimates. For example, research that was used as the basis of the Highway Economic Requirement System—State Version (HERS-ST) model indicate that the additional costs of a truck operating on poor pavement conditions is $0.23 per mile, while a recent National Cooperative Highway Research Program (NCHRP) study[10] estimated the additional costs at $0.04 per mile. Table 23 provides the increase in vehicle operating costs across all the pavement conditions using the NCHRP study and HERS-ST.

[10] National Cooperative Highway Research Program 720, Estimating the Effects of Pavement Conditions on Vehicle Operating Costs, 2012.

Table 23. Increase in Vehicle Operating Costs on Freight Intermodal Connectors.

Cost Increase	Category	NCHRP 720 Study	HERS-ST
Increase in Daily Truck Costs	Very Good	—	—
	Good	—	—
	Fair	$6,712	$40,857
	Mediocre	$3,331	$35,446
	Poor	$6,814	$39,937
	No Rating	$1,310	$9,035
	Total	$18,167	$125,275
Increase in Daily Auto Costs	Very Good	—	—
	Good	—	—
	Fair	$19,813	$226,438
	Mediocre	$15,887	$240,865
	Poor	$24,220	$249,557
	No Rating	$6,359	$76,078
	Total	$66,280	$792,938
Annual Total Increase in Costs (Millions)	Very Good	—	—
	Good	—	—
	Fair	$9.7	$97.6
	Mediocre	$7.0	$100.9
	Poor	$11.3	$105.7
	No Rating	$2.8	$31.1
	Total	$30.8	$335.2

Implications for Operations of Designated Freight Facilities

It does not appear the poor pavement conditions of freight intermodal connectors have a detrimental impact on freight facility operations. Truck drivers do not correlate increased wear and tear on their vehicles directly to their use of freight intermodal connectors. Truck drivers do not charge more to transport goods on roadways with poor pavement conditions compared to good pavement conditions. The cost of the increased maintenance and repair appears to be spread across their entire customer base and is not attributed to customers with facilities on poor connecting roads.

IMPACT ON CONGESTION AND CONGESTION COSTS

The FHWA National Performance Management Research Data Set (NPMRDS) was used to estimate truck travel speeds on freight intermodal connectors. Free-flow speeds were estimated based on late night speeds, and congestion was estimated based on a peak morning hour (8:00 a.m. to 9:00 a.m.), a midday period (12:00 p.m. to 1:00 p.m.), and a peak evening hour period (5:00 p.m. to 6:00 p.m.).

Based on measures used in the FHWA Office of Operations Performance Urban Congestion Report, congested speeds are defined as speeds less than 90 percent of free-flow speeds.[11] The figure shows that of the 901 connectors where speed data are available, 67 percent have at least one period where speeds meet this definition of congestion.

The total truck delay experienced on freight intermodal connectors in 2013 is estimated to be just over 4,000 hours every weekday based on analysis described in the Task 5 report. This equates to just over one million hours of truck delay annually on freight intermodal connectors. Using the percentages of truck (AADT) relative to total AADT, it can be estimated that the total annual auto delay on freight intermodal connectors is 12,181,234 hours. As shown in Table 24, using the value of time for truck and auto drivers based on the FHWA HERS, this equates to $353 million in congestion costs for all vehicles on freight intermodal connectors in 2013. Using a four percent discount rate over a 30-year period, the cumulative long-term congestion costs can be estimated at $6.4 billion.

Table 25 shows the estimated annual cost of delay on freight intermodal connectors by mode. It shows that port intermodal connectors have the highest estimated cost of delay with 37 percent of the $353 million total followed by airports and rail intermodal connectors with 32 percent and 23 percent, respectively. This is vastly different than the pavement costs to improve freight intermodal connectors which showed that nearly half of the improvement costs need to be applied to port intermodal connectors and only 18 percent to airport intermodal connectors.

Table 24. Annual Cost of Delay on Freight Intermodal Connectors.

Vehicle	Annual Hours of Delay	Hourly Cost of Delay	Total Costs
Trucks	1,059,238	$53.15	$56,298,500
Autos	12,181,234	$24.37	$296,856,673
Total	**13,240,471**	**N/A**	**$353,155,172**

(Source: Federal Highway Administration Highway Economic Requirements System estimated 2014 hourly values of travel time for five-axle trucks and medium autos.)

Table 25. Annual Cost of Delay on Freight Intermodal Connectors by Mode.

Vehicle	Total Costs	Percent of Total
Port	$131,246,395	37%
Rail	$82,348,710	23%
Air Cargo	$113,309,702	32%
Pipeline	$26,250,365	7%
Total	**$353,155,172**	**100%**

(Source: Federal Highway Administration Highway Economic Requirements System estimated 2014 hourly values of travel time for five-axle trucks and medium autos.)

[11] FHWA Operations Performance Measurement Program, The Urban Congestion Report (UCR), http://www.ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm, visited on August 24, 2015.

The cost of congestion on freight intermodal connectors can be compared to a cost estimate of adding capacity to alleviate the congestion by using estimated construction costs at State Departments of Transportation (DOTs). The cost to add a lane of capacity is estimated at $2 million per mile, exclusive of environmental and right-of-way costs, which can increase the cost of construction to $4 to $6 million per lane-mile. Based on these estimates, $3.2 billion would be enough to add capacity to 180 of the 540 most highly congested freight intermodal connectors.

This analysis indicates that benefits are likely greater than costs to add capacity to the most congested freight intermodal connectors, particularly in cases where there are limited environmental and right-of-way costs needed to increase this capacity. Benefit/cost analysis would need to be conducted on a case-by-case basis to determine the effectiveness of capacity investments on any particular freight intermodal connector.

IMPACT OF CONNECTORS ON BROADER SUPPLY CHAINS

Freight intermodal connectors work with other elements of the transportation system to form the freight infrastructure that supports goods movement. By considering the freight intermodal connectors relative to other freight infrastructure elements and their relevant supply chains, observations can be made about the importance, designation, and performance of freight intermodal connectors. This chapter examines the following three types of facilities and goods movement types:

1. A Port of Savannah truck drayage example.
2. A Memphis intermodal rail yard truck drayage example.
3. A generalized description of the two primary air cargo supply chains.

Supply Chain Example—Port of Savannah

In 2013, the Port of Savannah's annual cargo volume exceeded 3 million Twenty Foot Equivalent Units (TEUs). Between 20 percent and 25 percent of imported containers moving through the Port leave the facility by rail with the remainder being moved by truck. This results in nearly 5,000 truck trips in each direction at the Port of Savannah per day. Gate surveys of truck drivers at the Port of Savannah indicate that there are two types of general supply chains for trucks leaving the Port: 1) trucks that carry goods directly from the port to points outside of the Savannah region; and 2) trucks that make multiple drays in a day to carry goods between the Port and local distribution centers. The gate survey indicates that trucks moving between the Port and local distribution centers represent two-thirds of all trucks moving in and out of the port gates, or approximately 3,300 daily trucks.

Trucks that carry goods between the Port of Savannah and points outside of the Savannah region typically utilize the designated NHS intermodal connectors to reach I-95, including SR 21 (Augusta Road), SR 25, Grange Road, and Brampton Road. Alternatively, these trucks may utilize SR 307 (Bourne Avenue) to reach I-16. However, Bourne Avenue is not designated as an

NHS intermodal connector, which highlights the gap that often exists between roads that are used to connect to facilities and the roads that are designated as freight intermodal connectors. For the trucks that are carrying goods outside of the Savannah region, the nearest destinations include cities such as Atlanta, Georgia; Jacksonville, Florida; and Charlotte, North Carolina. Atlanta, which is 250 miles from the Port of Savannah, is the largest of these markets and a major inland freight hub in the southeast U.S. The travel between the Port of Savannah and Atlanta has five components, including a mix of travel on freight intermodal connectors in urbanized areas and interstate travel in both urban and rural areas, as described in Table 26 and shown in Figure 8.

Under free-flow conditions, the travel time on freight intermodal connectors relative to the total travel time can be estimated at seven percent of the total travel time, or 20 minutes of the roughly 5 hours of total travel time. If travel speeds on the freight intermodal connectors were to be reduced by one-half, which would constitute severely congested conditions, the total travel time would increase by 20 minutes. This increases the total travel time by seven percent, which translates to roughly $5 based on the FHWA HERS truck value of time. This can be compared to $80 in net income for the truck driver for making the trip. Therefore, even extremely slow or unreliable speeds on the freight intermodal connectors would not have a dramatic impact on this type of trip.

Table 26. Atlanta-to-Savannah Travel Time.

Travel Component	Distance (Miles)	Estimated Free-Flow Travel Speed (miles per hour)	Free-Flow Travel Time (Minutes)	Percent of Total Travel Time
Port to Interstate in Savannah using Designated Freight Intermodal Connectors	4	25	10	3%
Urban Interstate in Savannah Region	20	55	22	8%
Rural Interstate between Atlanta and Savannah	200	55	218	75%
Urban Interstate in Atlanta Region	30	55	33	11%
Atlanta Interstate to Final Destination (some travel on freight intermodal connectors)	4	25	10	3%
Total	**258**	***53**	**293**	**100%**

***** This number represents the average speed for the total trip.

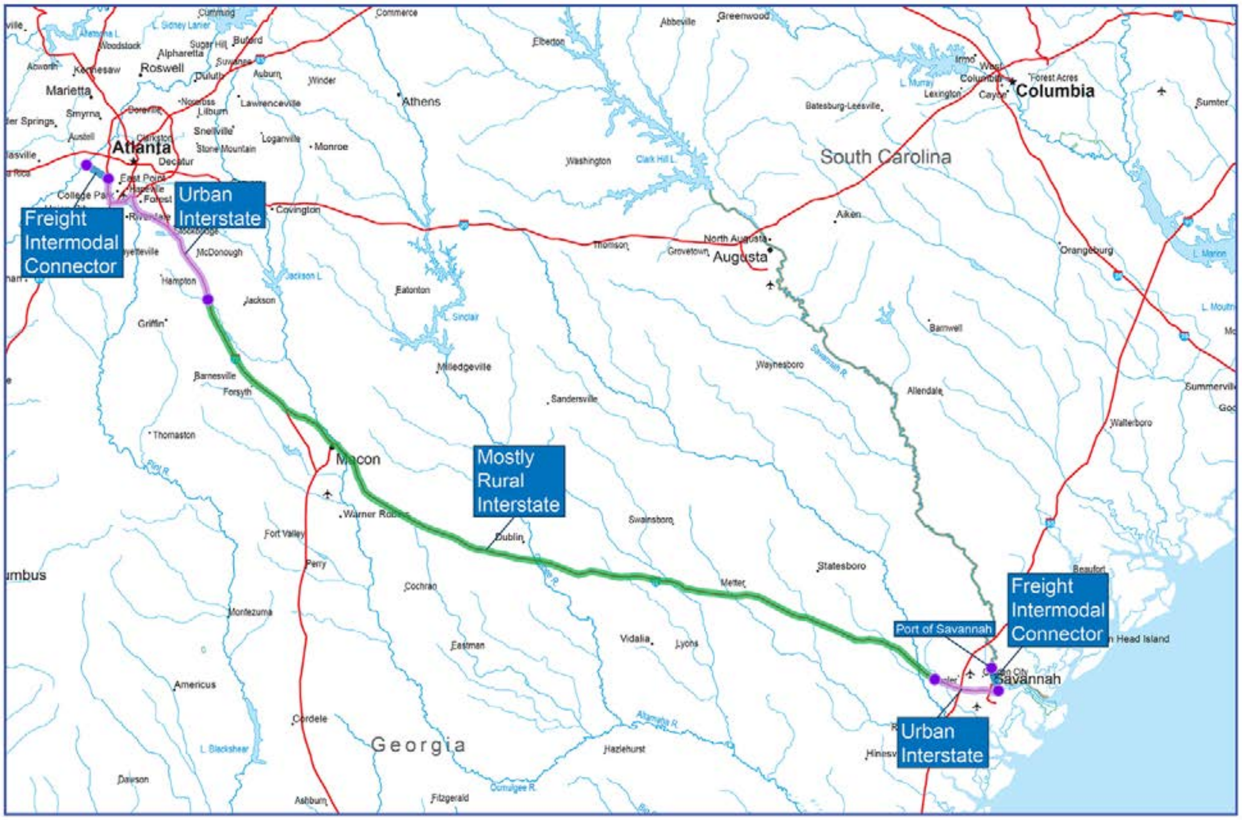

Figure 8. Map. Port of Savannah-to-Atlanta Truck Trip Components.
(Source: Federal Highway Administration)

For the trucks that are carrying goods between the Port of Savannah and local distribution centers, virtually all of the travel is on local roads. However, these local roads do not neatly align with the designated intermodal connectors. Figure 9 shows the desired lines of trucks (in red) surveyed at the Port of Savannah gates traveling to local warehouses and distribution centers. The trajectories of these lines are such that a portion of their trip occurs on the designated freight intermodal connectors, and another portion occurs on other local roads. Assuming that one-half of their travel occurs on the connectors and travel speeds are reduced by one-half on these connectors, then the productivity of drayage trucks that travel between the Port and the distribution centers would reduce by 25 percent. This would significantly increase the cost of port drayage operations and overall supply chains moving through the Port of Savannah. If travel on the local roads that are not designated as freight intermodal connectors is compromised, then productivity would be reduced even further.

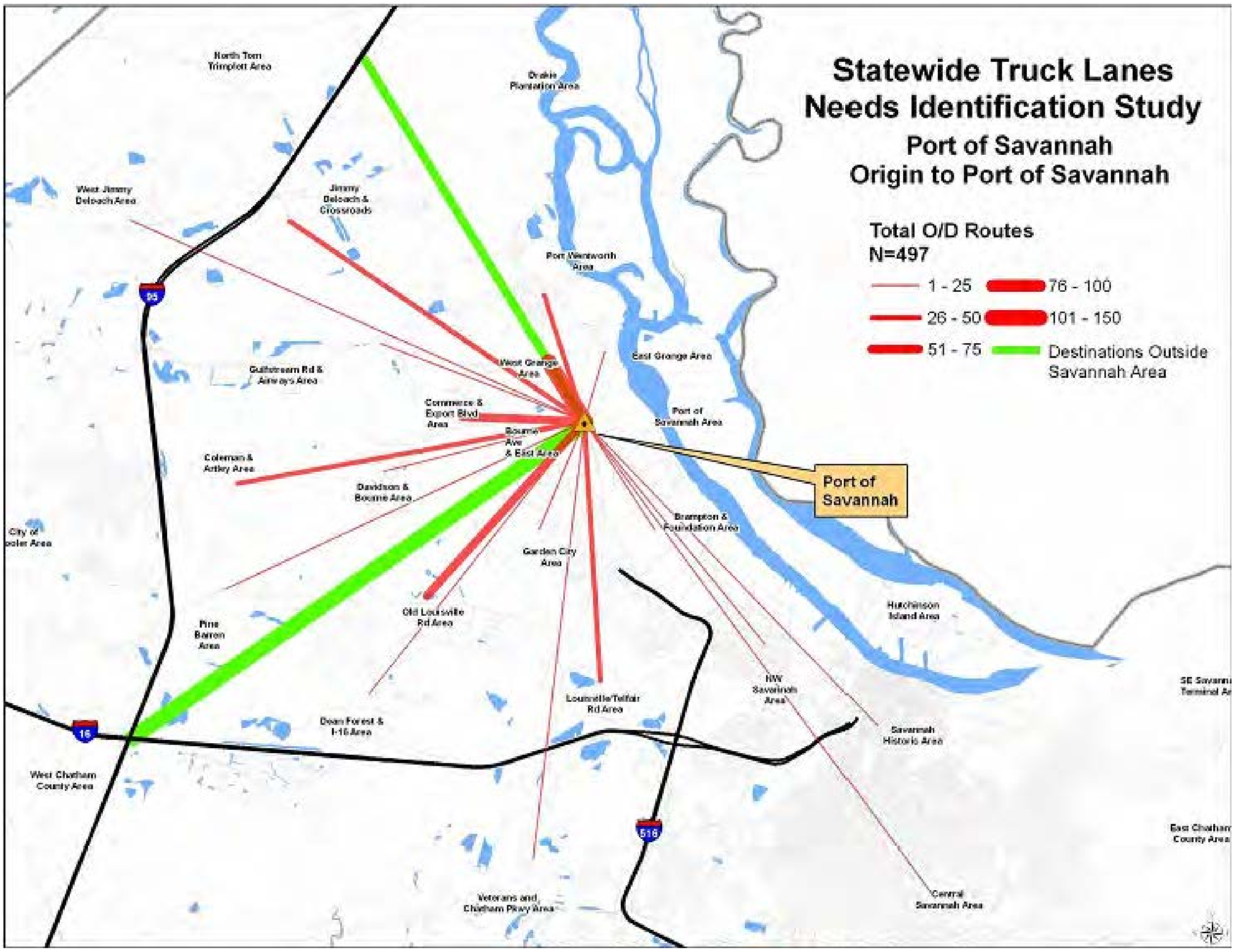

Figure 9. Map. Desire Lines for Port of Savannah Truck Trips.
(Source: Georgia Department of Transportation Truck Lane Needs Identification Study, 2006.)

The conclusion from examining truck trips from the Port of Savannah is as follows:

- For truck trips traveling from the Port directly to points further inland, the impact of the speeds of freight intermodal connectors is less significant than other factors such as the speeds on the Interstate System.
- For truck drayage moves between the Port and local warehouses and distribution centers, the impact of speeds on local roads is critical to truck productivity and important to overall port productivity. However, because freight intermodal connectors are not designated by connecting intermodal facilities to distribution centers, there is not necessarily an overlap between roads used for drayage and roads that are designated as freight intermodal connectors.

Supply Chain Example—Memphis BNSF Intermodal Rail Yard

BNSF operates an intermodal rail yard in Memphis, Tennessee on Lamar Avenue that serves domestic truck-rail movements. Trucks at this rail yard were surveyed as part of the Tennessee

DOT Lamar Avenue Corridor Study. Trucks also were surveyed at one point north of Lamar Avenue and one point south of Lamar Avenue. All of the surveyed trucks were recorded as either traveling to points within the sub-area or through the sub-area. Figure 10 shows the surveyed trucks leaving the BNSF intermodal yard. The trucks exhibited the following patterns:

- About 11 percent of the trucks surveyed utilize nearby Shelby Drive to access I-55. A small portion of Shelby Drive is designated as a freight intermodal connector, but it is not designated for the entire distance between the BNSF yard and I-55, so there is a mismatch between the designation and use of this roadway.

- About 15 percent of the trucks surveyed utilized South Perkins Road to access I-240, South Perkins Road also is not designated as a freight intermodal connector.

- Approximately 26 percent of the trucks surveyed utilize Lamar Avenue exclusively to leave the study area.

- The vast majority of the remaining 48 percent of trucks utilize local roads, some of which are designated as intermodal connectors to access local freight facilities in the sub-area. Trucks from these facilities likely distribute goods to several locations in the larger Memphis region.

The extensive use of local roads by trucks accessing the intermodal rail yard along with their relatively short distance traveled indicates that there is a strong connection between the performance of these local roads, the productivity of trucks accessing the intermodal rail yard, and the costs of the supply chain of goods moving through the rail yard. A severe reduction in the speeds of these local roads will reverberate through the supply chain.

Truck-following studies were also conducted at both ends of Lamar Avenue. Nearly one-half of these trucks traveled through the study region exclusively using Lamar Avenue. About six percent of the trucks utilized Shelby Drive to access I-55, and eight percent of these trucks used Shelby Drive to access local freight facilities. The vast majority of the rest of the trucks utilize Lamar Avenue along with other local roads to access local freight facilities. The volume of daily trucks accessing the intermodal rail yard is more than 1,000 trucks per day. However, it is still nearly an order of magnitude smaller than the 9,000 trucks per day along Lamar Avenue. Therefore, the truck travel patterns in the sub-area are still dominated by the trucks using Lamar Avenue to access freight facilities that are not the rail intermodal yard.

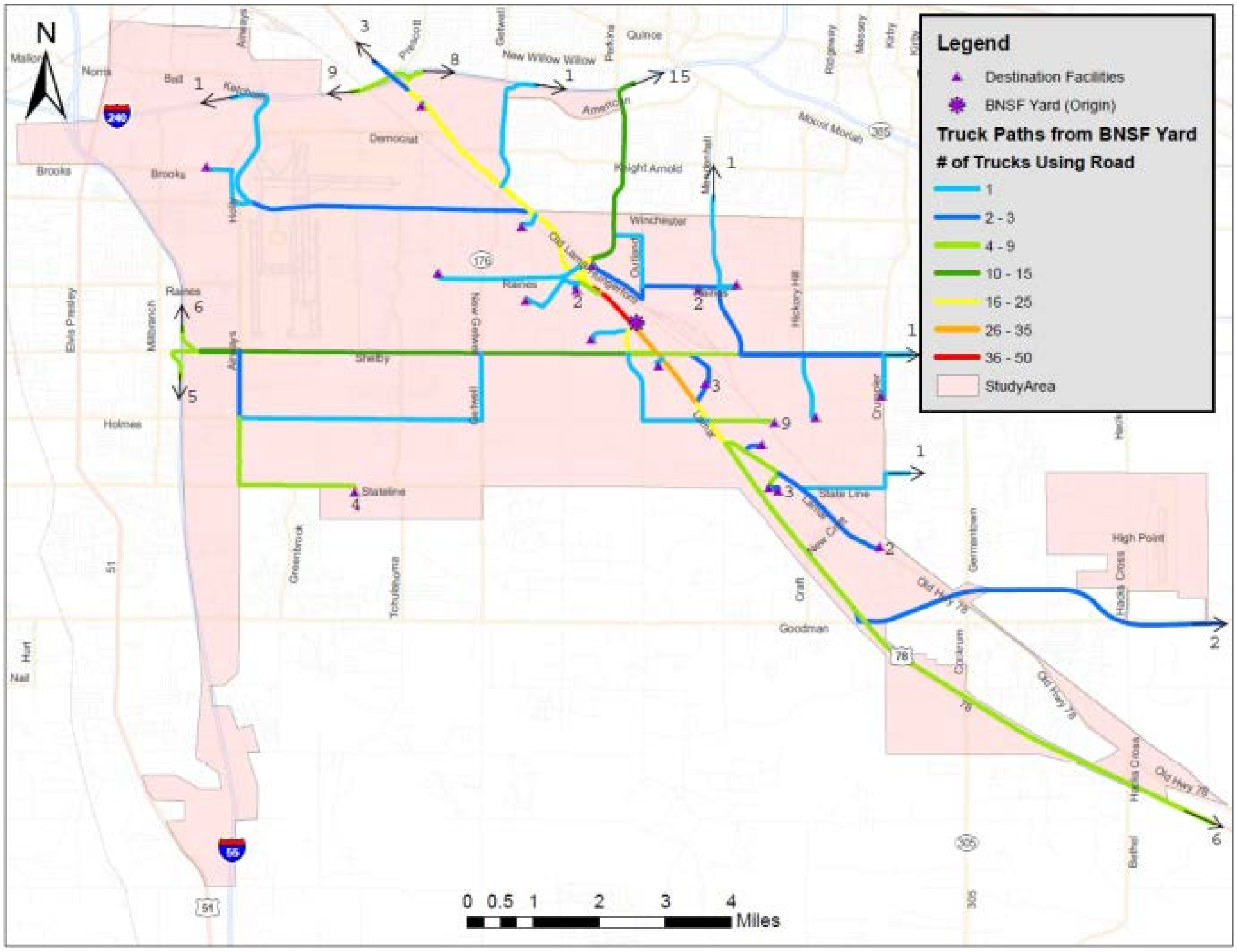

Figure 10. Map. Destinations of Trucks Leaving BNSF Yard.
(Source: Tennessee Department of Transportation Lamar Avenue Corridor Study, 2009.)

Note: Destination facilities with no numbers next to them received only one truck.

The implications of the truck travel patterns in the Memphis BNSF intermodal rail yard are as follows:

- There is a mismatch between the designated freight intermodal connectors and the roadways used between the rail yard and the nearby Interstate System.
- There is significant dispersion from the rail yard, such that there are several trucks that access nearby freight facilities on local roads that would likely not meet the minimum truck criteria for designation as a freight intermodal connector.
- The truck trip patterns from the intermodal rail yard are just a fraction of the truck activity in the industrial sub-area in which the yard is situated.

Supply Chain Example—Air Cargo

Air cargo traffic tends to fall into two categories: 1) industrial shippers with volumes per customer and high frequencies; and 2) consumer and business shippers with customers that have low and sporadic volumes that are integrated into larger shipment.

Industrial shippers tend to be serviced by freight forwarders and all-cargo carriers with catchment areas up to 600 miles. These large catchment areas are the markets served by the airport. Companies are willing to truck goods relatively long distances to take advantage of the lowest available air cargo rates that can be accessed within a one-day truck drive. There is significant competition between airports as most major companies are located within several catchment areas. For these types of supply chains, the performance of freight intermodal connectors is not a significant factor as the truck distances tend to be relatively long, and the travel time to the airport is not a critical component of supply chain costs or decisions.

Consumer and business shippers are serviced by integrated express carriers, such as DHL, FedEx Express, and UPS. Integrated services tend to have catchment areas up to 100 miles due to the need to be located within or very close to a large urban population center to generate volumes sufficient for operations. For integrated services, freight intermodal connectors serve an important role as the last mile between the Interstate and the air cargo facility. The reliability of travel speeds on connectors is critical as integrated services operate on regular schedules where unreliable travel times result in large buffer times being built in to scheduling, thereby increasing the number of vehicles and consolidation centers that are needed to serve the airport.

CHAPTER 6. SUMMARY OF KEY FINDINGS AND OPTIONS FOR FUTURE RESEARCH

This chapter describes key conclusions related to freight intermodal connectors. The key conclusions are grouped into the following categories:

- Designating freight intermodal connectors.
- Characteristics and use of freight intermodal connectors.
- Condition and performance of freight intermodal connectors.
- Data availability for freight intermodal connectors.
- Planning for freight intermodal connectors.
- Funding for freight intermodal connectors.

This chapter concludes with options to consider for future research into freight intermodal connectors. Most of these options for future research include identifying applications for the findings that were made throughout conducting the study.

KEY FINDINGS ON DESIGNATION OF FREIGHT INTERMODAL CONNECTORS

There are 798 designated National Highway System (NHS) freight intermodal connectors. The number of intermodal connectors has increased by 30 percent since the initial NHS designation. The number of port and rail connectors is likely to continue to increase as freight and supply chain trends indicate a continued increase in usage of intermodal containers for these modes.

Port intermodal connectors are the most common type of intermodal connector representing 40 percent of all freight intermodal connectors. Rail, airport, and pipeline intermodal connectors represent 26 percent, 26 percent, and 7 percent of freight intermodal connectors, respectively.

Designation of connectors has not kept pace with facts on the ground. There are some functionally obsolete and lightly traveled connectors that are still designated as critical NHS connectors. There are also some new, heavily used connectors that have not yet been added. Truck-truck terminals share many of the same characteristics as designated NHS freight terminals. Truck-truck terminals often attract large volumes of trucks to lesser used and local roads. Goods are stored, transloaded and reloaded back into trailers for delivery to final destinations. Many of these truck-truck terminals are co-located with rail intermodal facilities. However, many of the trucks that access the truck-truck terminals do not utilize the rail facilities. Additionally, they often utilize different access roads compared to trucks that are accessing the rail facilities.

KEY FINDINGS ON CHARACTERISTICS AND USE OF FREIGHT INTERMODAL CONNECTORS

There are approximately 1,484 miles of designated NHS freight intermodal connectors. The vast majority of freight intermodal connectors have relatively low capacity. Roughly half of the connectors are just two lanes, while roadways with three or four lanes represent another 40 percent of the total freight intermodal connectors.

Most freight intermodal connectors are relatively short with an average length of 0.98 miles. The distribution of connector lengths is skewed such that there are a small number of very relatively long connectors and 71 percent of the connectors are less than one mile in length.

Fifty-four percent of the freight intermodal connectors are owned by a city or municipal level highway agency. These connectors tend to be rather short with an average length of 0.68 miles. Twenty-nine percent of the freight intermodal connectors are owned by State highway agencies. These connectors have the highest average length of all ownership categories at 1.66 miles.

Many shippers and truckers perceive freight connectors as the entire roadway path between terminal gate and nearest Interstate highway. The current definition of connectors as the only link between the gate and the nearest NHS roadway (often a two- or four-lane State or local roadway that falls well short of Interstate standards) is inconsistent with the shipper and trucker perspective.

There were approximately 1,368,219 truck miles traveled on freight intermodal connectors in 2013. Over 1.2 million of these miles occurred in urbanized areas. Average truck volumes on freight intermodal connectors are 762 trucks per day. Airport intermodal connectors have the highest amounts of use in terms of both total vehicle volume and truck volume.

There are a small number of intermodal connectors that are carrying the bulk of the intermodal truck vehicle miles traveled (VMT). Nearly half of all of the intermodal truck VMT occurs on the top five percent of freight intermodal connectors in terms of volume. Ninety-seven percent of the truck VMT is captured on the top 50 percent of connectors.

While principal arterials (other) represent just 21 percent of all freight intermodal connectors, they carry roughly half of the truck VMT on freight intermodal connectors. This is in part due to the longer lengths of principal arterials and to their higher volumes.

State highway agencies are the owners of just 29 percent of the freight intermodal connectors. However connectors owned by State agencies carry 59 percent of the total connector truck VMT. The reverse is true for city or municipal highway agencies. They own 54 percent of intermodal connectors, but carry just 29 percent of connector truck VMT.

KEY FINDINGS ON CONDITION AND PERFORMANCE OF FREIGHT INTERMODAL CONNECTORS

The Highway Performance Monitoring System (HPMS) includes International Roughness Index (IRI) pavement condition readings at 1,239 locations across the 798 designated freight intermodal connectors. The average IRI value for all of these readings is 211, which rates as mediocre. Thirty-seven percent of the connectors rate as poor. Another 54 percent rate as either mediocre or fair. Only nine percent have a good or very good pavement condition.

Average IRI values for connectors owned by State highway agencies is 154 (fair) compared to an average value of 257 (poor) for city or municipal highway agencies. Combined with other findings, this reveals that there are two primary types of connectors:

1. Short, low-volume connectors owned by cities or municipal agencies with poor pavement condition.

2. Relatively long, high-volume connectors owned by State highway agencies with fair pavement condition.

Airport intermodal connectors have an IRI value of 155 (fair) which is significantly lower than the other freight modes, which are all on average rated as mediocre or poor. The higher pavement quality of airport connectors may be a result of fewer large trucks and/or better inclusion in the planning process.

It is estimated that between $30.8 million and $335.2 million in annual additional vehicle operating costs from connectors that do not have good pavement condition. This wide range of estimates indicates that there is the need for additional research on the full impacts of pavement condition on truck activity.

Average nighttime truck speeds (considered to be free-flow speeds) on rural connectors is 42 mi/h, much higher than the 28 mi/h average free-flow speed on urban connectors. There is notable congestion on freight intermodal connectors with daytime speeds consistently lower than free-flow speeds. On average, truck speeds drop on average 11 percent between free-flow and daytime speeds. Urban rail and port connectors have some of the most significant congestion issues with respective 21 percent and 14 percent speed drops between free-flow conditions and slowest daytime conditions.

Average truck speeds generally decrease as pavement conditions worsen. However, the average amount of congestion on a roadway did not increase for worse pavement condition. Additionally, there was not found to be a relationship between truck volumes and congestion, so connectors with low truck volumes are as likely to suffer from congestion as high truck volume connectors. In total, an estimated 4,237 hours of truck delay occur on freight intermodal connectors every day. Using the HERS-ST value of delay factors, this is equivalent to $353 million of annual additional costs for truck movements on connectors.

KEY FINDINGS ON DATA AVAILABILITY FOR FREIGHT INTERMODAL CONNECTORS

The HPMS database includes truck volume estimates on 88 percent of all designated NHS intermodal connectors and pavement condition estimates on 82 percent of the connectors. The NPMRDS database includes speed data on 52 percent of the connectors. These percentages are large enough to allow for generalizations to be made about the use, condition and performance of connectors. However, efforts to improve data availability will improve the usefulness of these databases in planning for a wider set of connectors.

Reporting to HPMS on conditions and performance of individual connectors is lagging. This is primarily due to the HPMS database not being designed to provide estimates on individual local roads with the type of unique characteristics that are featured on freight intermodal connectors. The inability of the HPMS to fully capture the conditions and performance of freight connectors affects assessments of national needs. Additionally, new truck speed and travel time data provide valuable insights into performance of connectors, but these are not currently incorporated into the HPMS. There is also a need for a closer linkage between GIS maps of networks, including connectors, and the HPMS database to allow information to move seamlessly across various platforms that include different types of data on freight connectors.

The most important data element to improve in terms of accuracy is truck volume data. To ensure accurate representation of freight activity, it is recommended that truck count data be collected on every freight intermodal connector every three to five years. Additionally, truck count data should include counts of both single-unit and combination vehicles. There are two options to consider in regards to improving State reporting of data on freight intermodal connectors:

1. Make increased data collection on connectors a requirement for continued inclusion in the designated freight intermodal connector program.

2. Make increased data collection on connectors a requirement for HPMS.

To balance the increased costs associated with counting truck volumes on freight intermodal connectors, allowances should be made to allow partial day counts, as long as the majority of the freight facility operating hours are captured in the data collection, and reasonable expansion factors are identified.

Another option that could balance the increased cost of a more detailed data collection on freight intermodal connectors is to reduce the number of roadways that qualify for designation into the freight intermodal program. Additionally, there should be consideration of removing roadways from the program when their volumes decrease beyond a certain level. It is interesting to note that, based on HPMS truck volume data, 198 of the designated freight intermodal connectors have volumes under 100 trucks per day, indicating that they would not qualify for the program if the application was occurring today.

An additional rationale for reducing the number of connectors in the program is evident in the distribution of truck volumes across the roadways. As noted in the Task 5 report, the highest 50 percent connectors in terms of VMT carry 97 percent of the total truck VMT. It would be reasonable to limit the designated NHS freight intermodal connector program to the top 50 percent of connectors in terms of VMT, because it would still capture the vast majority of truck VMT that occurs on connectors. A smaller number of freight intermodal connectors is also more consistent with the FHWA current tracking of speeds on intermodal connectors using the NPMRDS data, which focuses on just 43 miles of connectors compared to the 1,484 miles of designated NHS freight intermodal connectors.

A reduced number of designated freight intermodal connectors would also make it easier to improve and maintain data for several elements other than truck volumes. Additional improvements that could be made to the database include:

- Linking truck-involved crash data on the connector.
- Adding information on the number of trains, trucks and autos that are currently at railroad-grade crossings.
- Linking of roadway network identification between HPMS and NPMRDS for improved speed data conflation.

An alternative to reducing the number of designated freight intermodal connectors is to develop a two-tiered system, where connectors with volumes below a certain threshold are tracked using the current system, while connectors above the threshold are required to include more detail performance and activity data.

KEY CONCLUSIONS RELATED TO PLANNING FOR FREIGHT INTERMODAL CONNECTORS

Planning for connectors is very uneven. Considerable number of State Departments of Transportation (DOTs) and metropolitan planning organizations (MPOs) do not include connectors in regional models or truck route networks. Moreover, it is difficult for State DOTs and MPOs to forecast volumes of truck trip generated by terminals because current and future demand are often determined by economic conditions, business competition factors, and unforeseen technology developments.

There is a failure on the part of both the public and private sector to tell the story of intermodal connectors as critical links in freight transportation supply chains serving local economies and national and global markets. The conditions and performance of connectors are not measured as part of a freight path and network, are therefore not perceived as contributing to the economy, and consequently do not receive attention and funding.

The case studies revealed that freight intermodal connectors are often not specifically addressed in planning documents. Even freight plans do not systematically incorporate information on use, condition, and performance of freight intermodal connectors. Typically, in locations where freight intermodal connectors are incorporated into the planning process, it is the result of a freight champion that is aware of the importance of connectors, experienced in the transportation planning process, and has strong relationships within the private sector freight community.

There is sufficient data on freight intermodal connectors that can be readily incorporated into freight planning and general planning documents. Specifically, there is information on pavement condition and vehicle speeds that are generally available and reasonably accurate to describe the condition and performance of freight intermodal connectors. Additionally, information on crossings and bridge condition are available and can be incorporated as well. Truck and auto volume data are also available through the HPMS database, but should be verified by facility operators or through supplemental counts to improve the accuracy of this data.

The verification of connector volumes can be part of the broader outreach effort that is typically incorporated into planning efforts. The outreach should also include a qualitative description of the importance of each of the designated freight intermodal connectors along with documenting if there are designated connectors that are no longer used or new connectors that should be considered for designation. Issues related to land uses near connectors should also be documented, including encroachment, right-of-way preservation, and truck and non-truck volumes generated by new uses located along the connectors.

KEY FINDINGS ON COSTS TO IMPROVE CONNECTORS AND FUNDING FOR IMPROVEMENTS TO FREIGHT INTERMODAL CONNECTORS

It is estimated that the cost to improve pavement conditions on freight intermodal connectors to good quality condition is $2.2 billion. To increase capacity on congested connectors and to eliminate truck delays would cost an estimated $3.2 billion. This is exclusive of right-of-way costs that are relatively high in many urban areas where congestion is typically at its worst.

State and local funding sources targeted towards freight intermodal connectors are scarce. During the case study process, Florida was the only State identified as having a funded and active freight intermodal connector program. Typically, funds for connector improvements come from a combination of Federal, State, and facility operator funding sources that are general to transportation improvement.

There are a number of Federal transportation funding programs that can be used for freight intermodal connector improvements. The Fixing America's Surface Transportation (FAST) Act was signed into law in December 2015 and includes a number of provisions focused on ensuring the safe, efficient, and reliable movement of freight. The FAST Act establishes a new National Highway Freight Program to improve the efficient movement of freight on the National Highway Freight Network (NHFN) and supports several goals. Specifically, the FAST Act:

- Establishes a National Multimodal Freight Policy that includes national goals to guide decision-making.
- Requires the development of a National Freight Strategic Plan to implement the goals of the new National Multimodal Freight Policy.

- Creates a new discretionary freight-focused grant program that will invest $4.5 billion over five years. This program allows State, Metropolitan Planning Organizations (MPO), local governments, tribal governments, special purpose districts and public authorities (including port authorities), and other parties to apply for funding to complete projects that improve safety and hold the greatest promise to eliminate freight bottlenecks and improve critical freight movements.

- Establishes a National Highway Freight Program that provides $6.3 billion in formula funds over five years for States to invest in freight projects on the National Highway Freight Network. Up to 10 percent of these funds may be used for intermodal projects.

Freight intermodal connectors can also be funded and financed through the Federal programs available to all NHS roadways.[12] Specifically, the Federal funding programs, including the total funding allocated for fiscal year (FY) 2016 to FY 2020, available for freight intermodal connectors include:

- **National Highway Performance Program (NHPP)—**Provides $117.5 billion in Federal support for the condition, performance, and construction of the NHS.

- **National Highway Freight Program (NHFP**)—New $6.3 billion of formula funding from the FAST Act to improve the National Highway Freight Network (NHFN), which includes the primary highway freight network from MAP-21, critical rural and urban freight corridors, and the remaining Interstate highway system.

- **Nationally Significant Freight and Highway Projects—**New $4.5 billion grant program from the FAST Act, administered under Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE) grants, dedicated towards freight or highway projects of national or regional significance.

- **Surface Transportation Block Grant Program (STBG)—**Previously known as the Surface Transportation Program, STBG provides $58.268 billion in flexible funding that may be used to preserve and improve the conditions and performance on any Federal-aid highway, bridge and tunnel projects on any public road, pedestrian and bicycle infrastructure, transit capital projects, and freight projects.

- **Highway Safety Improvement Program (HSIP)—**$11.586 billion towards achieving a significant reduction in traffic fatalities and serious injuries on public roads, including non-State owned public roads and roads on tribal lands.

- **Congestion Mitigation and Air Quality Improvement Program (CMAQ)—**$12.02 billion funding source to reduce congestion and improve air quality. Available to State and local governments for transportation projects in nonattainment and maintenance areas.

12 Refer to the report Task 2—Data and Literature Search, Review, and Synthesis for a more in depth and detailed discussion of these programs as they relate to intermodal connectors.

- **U.S. Economic Development Administration (EDA) grants—**Funding available to develop infrastructure, including intermodal connector roads in economically distressed areas.

There also are several Federal financing tools that can be applied to freight intermodal connectors. These tools include:

- **Transportation Infrastructure Finance and Innovation Act (TIFIA)—**Originally established under MAP-21 and reauthorized under FAST Act, TIFIA provides financial assistance for projects to leverage Federal funds. This includes secured (direct) loans with flexible repayment terms, loan guarantees, and standby lines of credit as a secondary source of funding. Any project eligible for Federal assistance through existing surface transportation programs is eligible for the TIFIA program, including intermodal freight transfer facilities or projects that provide access to such facilities.

- **Grant Anticipation Revenue Vehicles (GARVEE)—**Established under MAP-21, GARVEE is a financing instrument that allows States to issue debt backed by future Federal-aid highway revenues. Eligibility for freight projects is constrained by the underlying Federal-aid programs that will be used for debt service.

The Appendix provides specific examples of how funding has worked for specific freight intermodal connector improvement projects.

OPTIONS FOR FUTURE RESEARCH FOR FREIGHT INTERMODAL CONNECTORS

There are several future research options to consider in regards to transforming the findings of this study into implementable recommendations that improve the tracking and performance of freight intermodal connectors. These options can be considered in the following five categories:

1. Consider changes to the criteria used to designate roadways as freight intermodal connectors.

2. Create a long-term data program for managing information related to designated NHS Freight intermodal connectors.

3. Identify options that will improve the quality and amount of data available for planning on freight intermodal connectors.

4. Generate recommendations for improving the performance tracking of freight intermodal connectors.

5. Develop guidance for systematically incorporating freight intermodal connectors into typical plans and programs that include freight elements.

APPENDIX. FUNDING PROGRAMS FOR FREIGHT INTERMODAL CONNECTORS

There are challenges to using existing transportation funding sources for freight intermodal connector projects. Federal transportation funding sources include programs categories such as the National Highway System (NHS) and Surface Block Grant Programs that are wide ranging and applicable to many different kinds of roadway projects, including projects not related to freight. Often, freight intermodal connector projects do not compete well with passenger-focused projects, because freight connectors tend to be local roads that are not frequently traveled by the general public. Similarly, transportation funding available at the State and local level tends to gravitate towards passenger transportation improvement projects.

The 2015 Fixing America's Surface Transportation (FAST) Act is the first of six Federal transportation funding legislations to include dedicated freight funding.[13] The FAST Act includes a freight funding program that is allocated to States based on a specific formula. This formula funding can be used towards intermodal connectors, particularly if they are designated as a critical urban or rural freight corridor, or if the connector is already part of the Interstate Highway System.

The FAST Act also includes a discretionary freight grant program called the Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE).[14] Under this program, the U.S. Department of Transportation (USDOT) solicits applications from the States to fund freight improvement projects that are critical freight and highway projects across the country. The FAST Act authorizes $800 million in funding for the FASTLANE program for fiscal year 2016. FASTLANE grants provide a substantial amount of funding, but for an intermodal connector to qualify for these grants, it must be considered nationally or regionally significant, and expected to contribute substantially to regional freight mobility.

Additionally, the National Multimodal Freight Network (NMFN) was established under National Multimodal Freight Policy as part of the FAST Act, which is intended to help strategically direct resources towards improving the NMFN's performance and achieve National Highway Freight Program goals. Intermodal connectors can be designated under the NMFN as strategic freight assets. Though there is no funding as part of this initiative, it will help guide investment decisions for States and private companies, and it may be used to allocate funding in future transportation legislation.

Identifying funding for improving freight intermodal connectors can be challenging. Although these connectors that are key to efficient operation of freight facilities, they are often not highly visible to public officials and decision-makers. Highlighting the needs of these connectors, generating solutions to address the needs and assembling needed funding to implement those

[13] More information on the FAST Act can be found at: https://www.fhwa.dot.gov/fastact.

[14] More information on the FASTLANE grants can be found at: https://www.transportation.gov/FASTLANEgrants.

solutions often requires the specialized knowledge and experience of freight champions (typically transportation planners).

Some intermodal connectors could receive funding via State programs that dedicate resources to freight improvement projects. However, only Texas and Florida had programs that may fall into this category. The State of Texas' Port Access Account Fund and the State of Florida's Seaport Investment Program both make funds available for port improvement projects within their respective States. In the case of Texas, however, though the program could be used to pay for improvements on port intermodal connectors the program was never funded. The State of Florida's program, on the other hand, is primarily for financing capital projects at ports.

Intermodal connector road access projects have been successfully funded through these programs and others. Table 27 summarizes projects that involved intermodal access improvements based on the 2007 FHWA *Financing Freight Improvements* Guidebook, including specific connector improvements made and funding sources. One takeaway from Table 27 is that successful connector improvements often leverage multiple funding sources, including private-sector funding sources. Another finding from the table is that funding for freight intermodal connector improvement projects are often part of a larger investment package.

Table 27. Examples of Successful Intermodal Connector Projects.

Project	**Description**	**Connector Improvements**	**Cost and Funding Sources**
Little Rock Port Authority Slackwater Harbor Improvements (Arkansas)	Railroad line extension, highway access improvements, dock construction and paved working area, warehouses, water/ sewer lines, drainage, product staging area, and bank stabilization work at the Little Rock Port Authority.	Connection of Harbor Drive to Frazier Pike Road, which provided direct access between the industrial park and the harbor.	$11.8 million, split between Federal (FHWA, Corps of Engineers, and EDA), State (Department of Economic Development, Arkansas State Highway Commission), and local (City of Little Rock, Little Rock Port Authority) sources.
Stockton Airport Freight Terminal (California)	Construction of an air freight terminal at Stockton Airport, including cargo apron improvement, stream relocation, and access road shoulder improvements.	Shoulder improvements to airport access road.	$1.7 million, $1.4 million of which was provided by a Federal Aviation Administration (FAA) Airport Improvement Grant. Matching funds were provided by the State of California and the City of Stockton, as well as a small contribution from Farmington Fresh, a private company that also paid for the $6.5 million cargo terminal on land it is leasing from the county.

Table 27. Examples of Successful Intermodal Connector Projects (continuation).

Project	Description	Connector Improvements	Cost and Funding Sources
Chicago Area Consolidation Hub (Illinois)	Access improvements to the UPS sorting facility in Chicago, including a new rail intermodal terminal, road access work, and a grade-crossing separation.	Interchange access from I-294 to Chicago Area Consolidation Hub, rail-highway crossing separation; and local street access improvements.	$97.6 million. The intermodal terminal was $70 million, which was 100 percent funded by BNSF. The road improvements were funded by a public-private partnership that included the State of Illinois, UPS, BNSF, and the Village of Hodgkins.
I-55 Access to CenterPoint Intermodal Center in Joliet (Illinois)	Construction of a new interchange on I-55 and improvements to Arsenal Road, which connects I-55 to the BNSF logistics park.	Arsenal Road improvements.	$36 million, of which $33.3 million was provided by Illinois DOT for the new interchange; $3 million for the road improvements came from the EDA.
Kedzie Avenue Access Road/ Stoplight in Chicago (Illinois)	Reconstruction of 1.5 miles of roadway, traffic signalization at a key intersection, and signal synchronization along Kedzie Avenue.	Kedzie Avenue provides access to the BNSF Corwith Yard.	$4.7 million provided by Chicago DOT ($4 million) and a Federal Congestion Mitigation and Air Quality (CMAQ) grant ($720,000).
Rochelle Intermodal Center/ UP Global III (Illinois)	Providing highway and rail access to the UP Rochelle Intermodal Center.	Road access to the facility.	$9.8 million, of which $4.3 million was provided by Illinois DOT for road improvements and another $2.2 million was provided by an EDA grant for water and sewer lines and roadway improvements.

Table 27. Examples of Successful Intermodal Connector Projects (continuation).

Project	Description	Connector Improvements	Cost and Funding Sources
Freight Action Strategy (FAST) Corridor (Puget Sound Region, Washington)	Series of improvements to key truck and rail infrastructure in the Seattle-Tacoma area to facilitate efficient freight movement in the region.	Investment packages included several connector projects, such as Spokane Street Viaduct widening at the Port of Seattle; East Marine View Drive widening at the Port of Everett; East Marginal Way-grade separation in Seattle; and South 228th Street-grade separation in Kent.	Funding typically is acquired from multiple sources, including public and private parties. As an example, the Spokane Street Viaduct project cost $168.5 million, split between the Federal Government, Washington State DOT, the City of Seattle, BNSF, the Port of Seattle, and the Washington Transportation Improvement Board.

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