“By tailoring freight plans and investments in light of regional trade specialties, federal, state, and local leaders will be able to support more efficient goods movement.”

Metro Modes

Charting a Path for the U.S. Freight Transportation Network

Joseph Kane and Adie Tomer

Summary

Trucks, railroads, waterways, airports, and pipelines represent the foundation of the country's freight infrastructure network. Yet mounting congestion costs and tight investment budgets require that we prioritize freight investments. Understanding the types of goods moved by each mode—and the major industries supported by these movements—is a crucial step for regions to take to address their freight challenges.

To assist in this process, this report uses data from the most recent year available (2010) to examine how U.S. regions move goods between each other. It finds that:

- **Trucks exclusively move more than two-thirds of the volume of all U.S. goods, but several other transportation modes carry high-value products and bulk commodities critical to regional economies.** Over recent decades, trucks have consistently carried the most goods nationally, up to 75 percent of the value and weight of commodities ranging from electronics to agricultural products. In contrast, air modes tend to move innovative, high-value commodities like precision instruments, while railroads and pipelines specialize in raw commodities like energy.
- **The country's 100 largest metropolitan areas are the major hubs of U.S. freight activity, moving more than $8.1 trillion, or 60 percent, of all the nation's goods that travel by truck.** Across all modes, populated markets like New York, Chicago, and Los Angeles move enormous freight volumes, and their preferred transportation modes influence national flows. Although trucks dominate in most of these areas, the presence of specific industries—and commodities—in different markets often translates to unique modal dependencies and infrastructure needs throughout the country's goods trade network.
- **Neighboring metropolitan areas can depend on trucks for 90 percent or more of their freight activity, heavily influencing their infrastructure needs.** From New York and Philadelphia to San Diego and Los Angeles, trucks move the broad majority of goods between markets separated by less than 500 miles. Over longer distances, however, air modes, railroads, and pipelines can account for a much higher share of goods movement, particularly depending on the type of commodity.

This report illustrates how trucks frequently serve as a backbone for the nation's entire freight network, but also reveals how several other modes are essential to support the exchange of specific goods between metropolitan markets. Those aggregate trends have enormous implications for future infrastructure investment. By tailoring freight plans and investments in light of these regional trade specialties, federal, state, and local leaders will be able to support more efficient goods movement, respond more directly to local industrial needs, and drive more robust economic growth.

Background

Trade fuels metropolitan economies, as a constrant stream of goods flows between producers and consumers worldwide.[1] From machinery and electronics to textiles and energy products, metropolitan areas exchange an assortment of commodities with one another to generate economic growth. But all of that trade would be impossible without an enormous freight infrastructure network to transport goods between domestic and international trade partners.[2] Throughout the United States, more than 200,000 miles of highways, 140,000 miles of railroads, 12,000 miles of waterways, and 2.6 million miles of pipelines—in addition to hundreds of airports, seaports, and intermodal faciltiies—represent the major physical links binding regions together.[3]

Across the public and private sector, however, there has been a continued lack of investment and coordinated leadership at the national, state, and local level to support this freight network, which handles an ever-growing amount of goods each year, valued at $20 trillion and weighing 17 billion tons in 2010 alone.[4] For example, federal leaders frequently divorce national transportation policies from national trade policies, while failing to tailor freight plans and investment programs in light of place-specific economic needs.[5] Disjointed, incrementally built policies across different modes and jurisdications also fail to articulate the goals for individual projects. Moreover, widespread capacity constraints at many freight facilities—combined with questions over future federal funding, an inefficent project selection process, and limited coordination between different regional stakeholders—hold back efforts to address systemwide concerns.[6]

Among these concerns, highways remain a key focal point, with almost 11 million trucks traversing U.S. interstates every year.[7] Congested urban interchanges, port connectors, and border crossings clog the reliable flow of goods to firms, factories, warehouses, and households.[8] As the number of vehicle miles traveled by trucks on highways increases over time—a total that has grown by 84 percent since 1990 compared to 38 percent growth across all vehicles—chokepoints are likely to worsen and further encumber shippers.[9] At the same time, ongoing shortfalls in the Highway Trust Fund, questions over future revenue sources, and prolonged uncertainties in state budgets continue to stall sorely needed maintenance projects.[10]

Increased demands on railroads have also escalated pressures on the U.S. freight network. Boasting greater fuel efficiencies and lower shipping costs in many areas, railroads are expected to see their traffic nearly double by 2035, largely due to high volumes of chemicals and other energy products, including oil.[11] Primarily concentrated along corridors owned by large Class I railroads like BNSF, CSX, and Norfolk Southern, private investment needs will balloon to more than $175 billion for new tracks, signal upgrades, and related expansions over the next two decades.[12] Beyond the need for increased private investment, public leaders are also confronting widespread delays at rail crossings and a variety of other concerns near key intermodal exchanges.[13]

Similar investment concerns have emerged across the nation's pipelines as well as its inland and intracoastal waterway system. Following the shale gas boom, oil and natural gas pipelines have struggled to keep up with growing shipments to the Gulf Coast and other refinery centers, with expansion costs estimated at over $250 billion in the next 25 years.[14] Meanwhile, significant volumes of grain, petroleum, and other critical resources transported along the nation's waterways face bottlenecks as a result of inadequate locks, rapidly aging dams, and delayed dredging projects.[15]

A number of financial and operational challenges have coincided with the growth in air cargo and multimodal freight activity as well. While these modes have helped strengthen U.S. global connectivity, the need to reliably ship high-value, time-sensitive products like precision instruments often requires careful monitoring and coordination among several different public and private actors.[16] Capacity-enhancing investments, such as the Federal Aviation Administration's (FAA) Next Generation Air Transportation System (NextGen), are becoming a necessity in today's global value chains along with a host of other physical upgrades at terminal facilities, which depend on sustainable plans and funding.[17]

As a consequence, public and private leaders face a pressing need to target investments across these various infrastructure assets, with an eye toward unifying them in a more integrated freight network.[18] This need is especially critical in the nation's largest metropolitan areas, which are the source for more than $16.2 trillion (80 percent) of the country's freight and function as its primary trade hubs.[19] The highly concentrated nature of this network, in turn, means that a relatively small group of metropolitan trade corridors carry the highest volume of goods and influence freight efficiencies for the entire country.

However, accomplishing this task remains a difficult challenge at the federal, state, and local level. Existing federal programs are not only fractured across three different legislative vehicles, but they often use arbitrary criteria, lack project accountability, distribute resources thinly across different regions, and focus almost exclusively on improving highways.[20] While states are developing their own freight plans to improve connectivity—as the most recent surface transportation legislation, the Moving Ahead for Progress in the 21st Century Act (MAP-21), recommended—prioritizing and financing projects of regional significance stands as a complex endeavor. Locally, public and private stakeholders are also struggling to forge partnerships, execute plans, and coordinate more efficient land use decisions in the face of tightening budgets and rapidly rising freight volumes.[21]

To better guide these planning and investment decisions, this report explores how the U.S. moves freight. It uses a comprehensive goods trade database to examine the major transportation modes that operate between different metropolitan areas. After describing recent national patterns, the report looks into the ways regions trade with each other, both in aggregate and in terms of their commodities. The report then dives deeper into how modes vary among individual metropolitan trade partners and highlights the importance of distance and industrial specialties to their freight profiles. Finally, the report concludes with a discussion of how policymakers can use these metrics to chart a new path forward for freight, grounded in the economic primacy of the country's key trade corridors.

Methodology

As with previous reports in the Metro Freight series, this report concentrates on the movement of goods between different metropolitan and nonmetropolitan areas and highlights the specific types of transportation modes used nationwide. As such, this trade analysis aggregates the exchange of products among all industries and private households present in these domestic regions. By focusing on the physical sites of production and consumption—as opposed to just freight hubs and ports—the report examines the economic connections underlying the nation's freight movement.

This report uses a unique database, developed by Brookings and the Economic Development Research Group (EDR), to examine goods traded among different regions. While the U.S Department of Transportation's Freight Analysis Framework (FAF) serves as a statistical foundation, the database defines goods movement at a more precise metropolitan scale, measuring the total value and weight of goods transported to, from, and within the United States in 2010. These domestic and international movements can be seen across 17 commodity groups and seven transportation modes. Due to changes in FAF accounting between versions, the database contains only one statistical year and does not permit longitudinal analysis.

The database includes the exchange of goods across 409 domestic areas (361 metropolitan areas and 48 state remainders) and 40 international geographies (18 countries, 11 larger country groups, and 11 continental remainders). This report views these exchanges in terms of the aggregate value of goods moved domestically, including the transport of goods to and from specific U.S. ports. For example, the total amount of goods moved by truck between Los Angeles and Bakersfield, Calif. not only refers to domestic products that start or end in these two markets, but also includes imports and exports processed through port facilities. In this way, the analysis excludes modes that transport goods internationally beyond U.S. borders, such as ocean vessels. For a complete discussion of this report's methodology, see Appendix A.

TRANSPORTATION MODES[22]

Truck: includes private and for-hire trucks. Private trucks are owned or operated by shippers, and exclude personal use vehicles hauling over-the-counter purchases from retail establishments.

Rail: includes common carriers and private railroads, encompassing a range of Class I, II, and III companies.

Water: includes inland and intracoastal waterway movements. Shallow draft, deep draft, and Great Lakes shipments are also counted in this modal category.

Air (includes truck-air): includes shipments typically weighing more than 100 pounds that move by air or a combination of truck and air in commercial or private aircraft. Also includes air freight and air express.

Pipeline: primarily includes energy shipments via oil pipelines as well as flows from offshore wells to land.

Multiple modes and mail: includes truck-rail, truck-water, and rail-water intermodal shipments involving one or more end-to-end transfers of cargo between two different modes. It is not limited to containerized cargo, and also includes parcel delivery services.

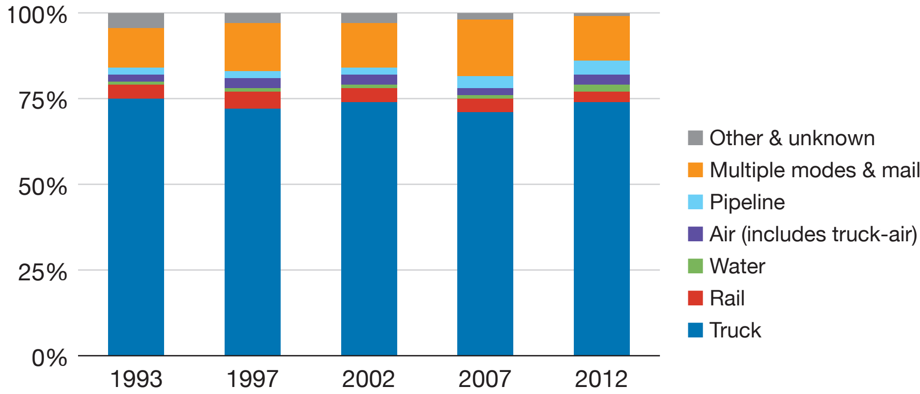
Other and unknown: includes miscellaneous and other types of transportation.

Findings

Trucks exclusively move more than two-thirds of the volume of all U.S. goods, but several other transportation modes carry high-value products and bulk commodities critical to regional economies.

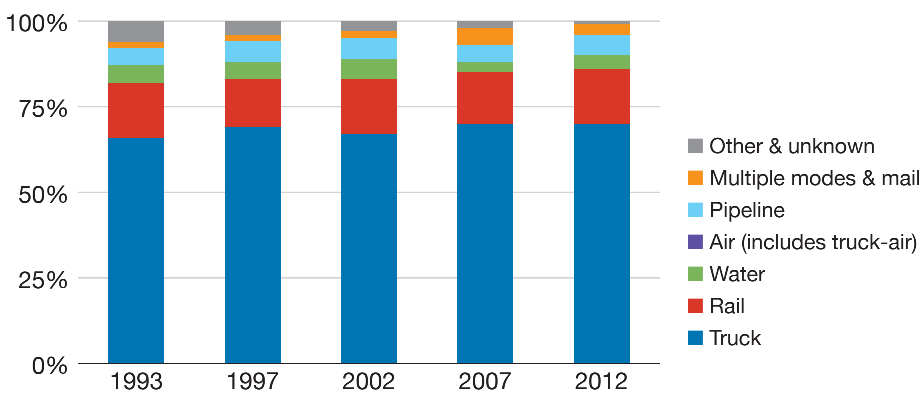
Throughout the country, regions depend on an efficient, well-integrated infrastructure network to exchange goods with other markets. Although many different freight assets, such as airports, railroads, and waterways, support this network, trucks have long represented the most signficant mode of transport stitching regions together. Over the past two decades, trucks have consistently moved nearly 70 percent of goods within the United States (Figures 1 and 2), whether measured by value or weight. In 2010—this report's primary focus year—trucks carried $13.6 trillion and 9.8 billion tons of goods. Trucking also plays a vital role in multimodal shipments, often providing the first and last mile transport needed to connect the other modes to factories, warehouses, and stores. This immense concentration of freight activity on the nation's highways has resulted in more traffic, the demand for better managed roadways, and the need for increased public investment.[23]

Figure 1. Modal Share of Total Goods Trade, by Value



Source: Brookings analysis of Commodity Flow Survey data

Figure 2. Modal Share of Total Goods Trade, by Weight



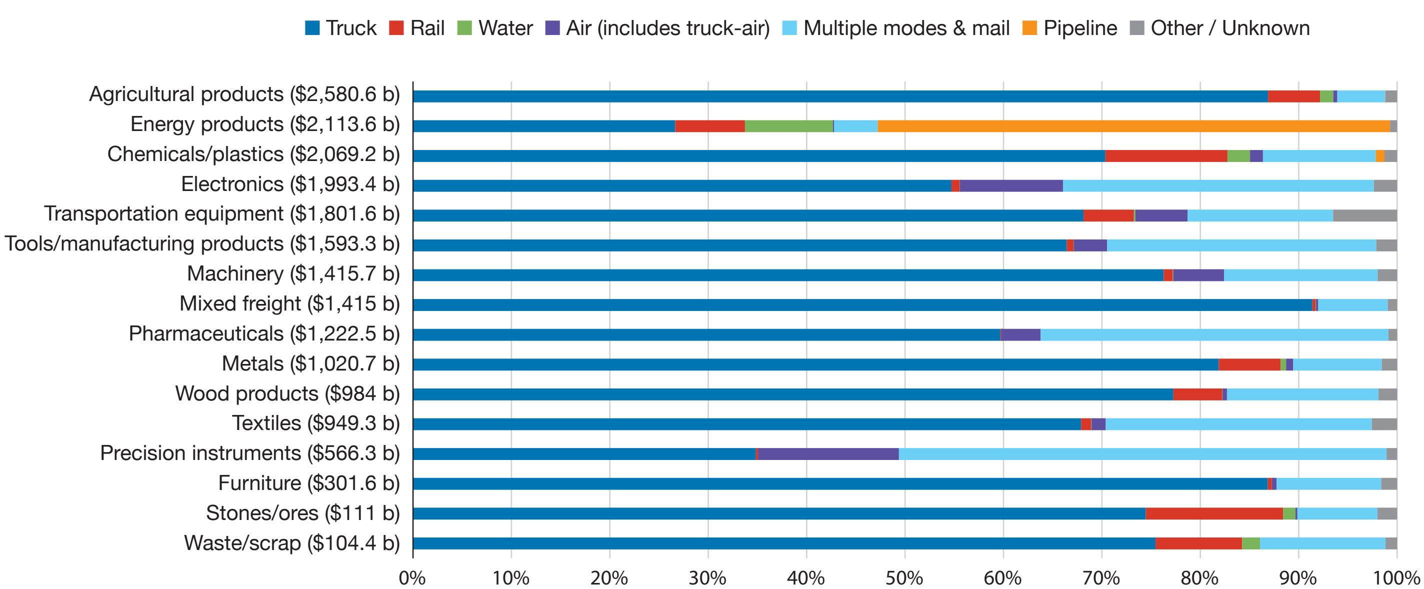
Source: Brookings analysis of Commodity Flow Survey data

By comparison, multiple modes move about one-quarter the value ($3.4 trillion) and one-tenth the weight (892.2 million tons) that trucks do nationally, yet have assumed a central role in freight over the past several years. The rise of containerization across different modes, coupled with other technological improvements, has helped integrate transportation in global trade, allowing regions to ship a vast array of goods in a safer, faster, and more cost-effective manner.[24] In the same way, air modes move considerably less value ($631.2 billion) and weight (35.5 million tons) overall, but they are indispensable in shipping a variety of refined products quickly to metro areas nationwide.

On the other hand, railroads ($825.6 billion and 3.2 billion tons), pipelines ($1.1 trillion and 2.1 billion tons), and waterways ($279.1 billion and 799.9 million tons) focus less on moving large volumes of valuable goods and more on hauling massive amounts of bulk commodities between regions. Combined, these three modes account for 36 percent of total U.S. freight weight, but less than 11 percent of U.S. freight value.[25]

In most cases, the specific goods that regions produce, consume, and trade with one another influence the types of modes used to drive their economic connectivity, with trucks playing a lead role. As Figure 3 illustrates, trucks carry all types of goods at high rates, including at least 75 percent of the total value of most commodities. These amounts range from $1.1 trillion in machinery (76 percent) to $2.2 trillion in agricultural products (86 percent). Even heavy, raw products like stones/ores typically travel on trucks, both by value (74 percent) and weight (68 percent). Mixed freight, which includes miscellaneous food and supplies for offices and stores, also depend the most on trucks (91 percent by value) to reach many highly populated markets.

Figure 3. Modal Share of Total Goods Trade, by Commodity and Value, 2010

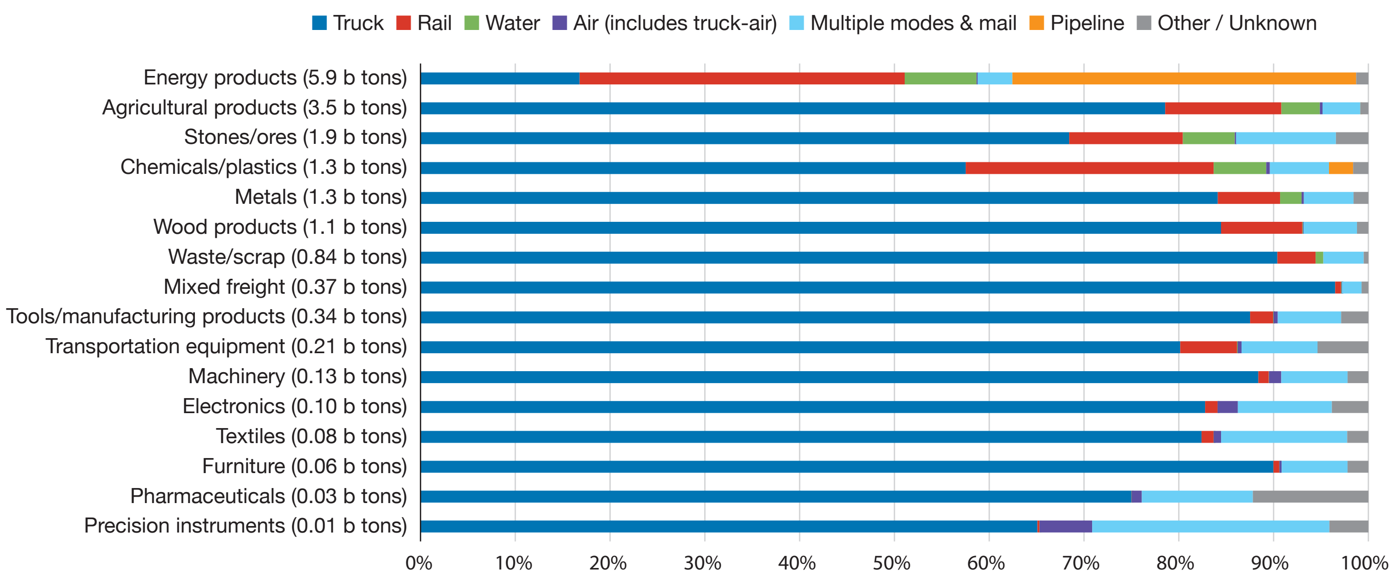


Source: Brookings analysis of EDR data

While trucks are integral for all kinds of commodities, movements involving precision instruments, pharmaceuticals, and similar advanced industrial (AI) goods frequently depend on a wider variety of freight assets.[26] For instance, almost $940 billion of transportation equipment, chemicals/plastics, and tools/manufacturing products travel on multiple modes. Likewise, electronics and precision instruments represent two of the three largest types of air cargo ($290 billion). Based on their presence in global value chains, many of these lightweight AI goods depend on aviation to connect high-tech firms, manufacturing plants, and assembly facilities between distant markets. Air modes transport goods worth $17,760 per ton, far eclipsing multiple modes ($3,790 per ton), trucks ($1,390), pipelines ($510), waterways ($350), and railroads ($260).

Energy products stand out in their modal variety as well (see box, "Freight's Evolving Role to Move Energy Products"). Together, railroads and pipelines carry nearly 60 percent of these commodities nationally ($1.2 billion) and more than double the total value moved by trucks ($542 million). By weight, their share increases to almost 70 percent (4.1 billion tons), more than quadruple the total by trucks (970 million tons), as revealed in Figure 4. With coal, crude petroleum, and fuel oils ranking among the largest energy products, many refineries along the Gulf Coast and elsewhere rely extensively on these two modes to connect with their trade partners.

Figure 4. Modal Share of Total Goods Trade, by Commodity and Weight, 2010



Source: Brookings analysis of EDR data

UNDERSTANDING FREIGHT'S EVOLVING ROLE TO MOVE ENERGY PRODUCTS

Over the past five years, technological advances and shale gas discoveries helped U.S. crude oil production soar to new heights. The country produced more than 3.1 billion barrels in 2014—equivalent to almost 8.6 million barrels per day.[27] Experts predict that by 2020 daily production will jump to more than 11.1 million barrels per day, higher than any other producer, including Saudi Arabia.[28] This surge in supply is not only transforming the nation's energy landscape from North Dakota to Texas, but also rapidly mounting pressure on the freight infrastructure that connects its numerous producers, refiners, and consumers—prompting additional investment in years to come.

While the U.S. continues to import more crude oil than it exports, partially due to an export ban in existence since the 1973 global oil crisis, the domestic transportation network is straining to handle rising loads of energy at home.[29] In a system designed to transport oil imports to coastal refineries, existing pipelines are at or near capacity in many locations, while trucks, barges, and trains are stepping in to handle a huge wave of domestic shipments often headed to entirely new markets.[30]

Railroads, in particular, have experienced a spike in demand, transporting over 371.2 million barrels of crude oil in 2014 compared to only 20.2 million barrels in 2010—an astonishing 1,842 percent increase.[31] From the Canadian oil sands to the Bakken oil fields, the lack of direct pipeline connectivity makes railroads the only viable mode to move large, heavy crude reserves over long distances to national refineries. In total, there are more than 140,000 miles of railroad spanning the country, significantly more than the 61,000 miles of crude oil pipelines.[32] Railroads also offer more flexibility than oceangoing tankers and coastal barges that are frequently limited to a narrower range of markets near navigable waterways.[33]

As a result, public and private leaders are increasingly shifting their attention to the large volumes of oil, natural gas, and other energy products shipped along the nation's railroads, even while debates continue to rage on expanding pipelines, led most notably by the Keystone XL project.[34] On the one hand, firms such as CSX and BNSF are eager to take advantage of this energy revolution, aiming to gain greater marginal returns and to diversify their cargo beyond coal and related products.[35] Meanwhile, policymakers at the national and state level are calling the safety and environmental impact of these rail movements into question following the Lac-Mégantic oil spill in Canada, as well as more recent accidents in Casselton, N.D., and Lynchburg, Va.[36]

The rising importance of railroads in the nation's energy movements, however, stretches far beyond quarterly earnings and tank safety requirements. As part of a larger freight network that carries a wide assortment of goods, railroads serve as a vital link between many individual markets, including those focused on agricultural products and other bulk commodities. For example, with energy products forcing railroads to delay grain, soybean, and related shipments, farmers are struggling to distribute their goods across the country and facing millions of dollars in backlog costs.[37] Lingering concerns over the sustainability and environmental safety of hydraulic fracturing and other emerging energy extraction practices also continue to hover over these rail movements.[38] As railroads continue to evolve in the U.S. freight network, policymakers will need to continually monitor the direct and indirect impacts of these developments on industries nationwide.

The country's 100 largest metropolitan areas are the major hubs of U.S. freight activity, moving more than $8.1 trillion, or 60 percent, of all the nation's goods that travel by truck.

Given the highly concentrated nature of the national trade network—with most high-value, innovative U.S. goods sourced in the country's 100 largest metro areas—it stands to reason that these same areas represent the primary centers for freight traffic across all types of modes (Table 1).[39] Similar to the nation as a whole, trucks lead in the amount and variety of commodities ($8.1 trillion) they carry in these busy markets, which has resulted in numerous pinchpoints throughout the interstate highway system.[40] Significant volumes of air cargo ($449.0 billion) and multimodal shipments ($2.3 trillion) also cycle through these large markets, which handle about 70 percent of such movements nationally.

Table 1. Share of Total U.S. Goods Trade Value, by Region and Mode, 2010 ($ millions)

Mode	Total U.S. Value	100 Metro Areas	Top 100 Share	Other Metro Areas	Other Metro Share	Nonmetro Areas	Nonmetro Share
Truck	$13,631,104.1	$8,104,512.7	59.5%	$3,176,230.5	23.3%	$2,350,360.9	17.2%
Rail	$825,626.0	$395,535.9	47.9%	$166,400.0	20.2%	$263,690.0	31.9%
Water	$279,053.3	$149,389.0	53.5%	$74,923.4	26.8%	$54,740.9	19.6%
Air (includes truck-air)	$631,159.4	$449,025.1	71.1%	$93,434.9	14.8%	$88,699.5	14.1%
Multiple modes & mail	$3,374,053.4	$2,257,816.6	66.9%	$552,194.9	16.4%	$564,042.0	16.7%
Pipeline	$1,077,990.0	$588,352.6	54.6%	$196,601.8	18.2%	$293,035.6	27.2%
Total*	**$20,293,847.6**	**$12,234,613.0**	**60.3%**	**$4,352,978.0**	**21.4%**	**$3,706,256.6**	**18.3%**

** Note that totals include values not shown individually for "other and unknown" modes as well as "no domestic mode"*

Source: Brookings analysis of EDR data

In contrast, nonmetropolitan areas tend to lean more heavily on railroads, pipelines, and waterways, particularly for their heaviest goods like energy products, wood products, and stones/ores. Although these less-populated, predominantly rural regions move far fewer products compared to the largest metropolitan areas—and thus a lower share of all U.S. goods by weight (31.4 percent)—their rail movements (1.8 billion tons) still account for 54.4 percent of the national total (Table 2). Carrying 835.1 million tons combined, waterways and pipelines connected to nonmetro areas also make up a sizable chunk of total U.S. weight.

Table 2. Share of Total U.S. Goods Trade Weight, by Region and Mode, 2010 (thousands of tons)

Mode	Total U.S. Weight	100 Metro Areas	Top 100 Share	Other Metro Areas	Other Metro Share	Nonmetro Areas	Nonmetro Share
Truck	9,809,513.8	4,762,414.1	48.5%	2,594,310.4	26.4%	2,452,789.3	25.0%
Rail	3,237,509.3	897,827.1	27.7%	580,083.2	17.9%	1,759,599.0	54.4%
Water	799,912.3	372,382.5	46.6%	199,807.8	25.0%	227,722.0	28.5%
Air (includes truck-air)	35,547.7	19,598.7	55.1%	6,908.6	19.4%	9,040.4	25.4%
Multiple modes & mail	892,234.2	407,593.7	45.7%	183,856.7	20.6%	300,783.8	33.7%
Pipeline	2,131,004.0	1,140,441.3	53.5%	383,234.8	18.0%	607,327.9	28.5%
Total*	**17,343,394.6**	**7,828,132.4**	**45.1%**	**4,067,300.8**	**23.5%**	**5,447,961.5**	**31.4%**

**Note that totals include values not shown individually for "other and unknown" modes as well as "no domestic mode"*

Source: Brookings analysis of EDR data

In all these cases, the presence of specific industries—and commodities—in different regions often reveals unique modal dependencies and infrastructure needs throughout the country's goods trade network. This is particularly true in the 100 largest metro areas, which frequently produce, consume, and distribute the most valuable commodities. As one example, these markets exchange over $310 billion in precision instruments between each other annually, 61 percent of which ($189 billion) travel by air or multiple modes and are valued at over $118,000 per ton. Likewise, while trucks carry the most pharmaceuticals, electronics, and transportation equipment between the 100 largest metro areas, more than $847 billion (37 percent) of these three commodities still depend on reliable air and multimodal connections (see box, "The Rise of Intermodal Freight").

The huge influx of raw, bulk commodities into the 100 largest metro areas also signals the importance of having reliable freight connections with other metropolitan areas and nonmetro areas alike.[41] For example, of the $738 billion in agricultural products the 100 largest metro areas take in annually, $325 billion travels by truck from smaller metro areas and nonmetro areas, revealing how crucial highways are for the timely arrival of such goods.[42] In addition, the tremendous imbalance of energy products streaming into the 100 largest metro areas—which run an energy deficit of $237 billion annually—illustrates how critical it is for pipelines and railroads to connect these populated markets to sites of energy extraction.

Consequently, as policymakers look to forge new plans and partnerships to generate additional trade in years to come, highways and several other complementary freight assets demand their attention, primarily depending on the industrial activities that are core to regional economies.[43]

THE RISE OF INTERMODAL FREIGHT

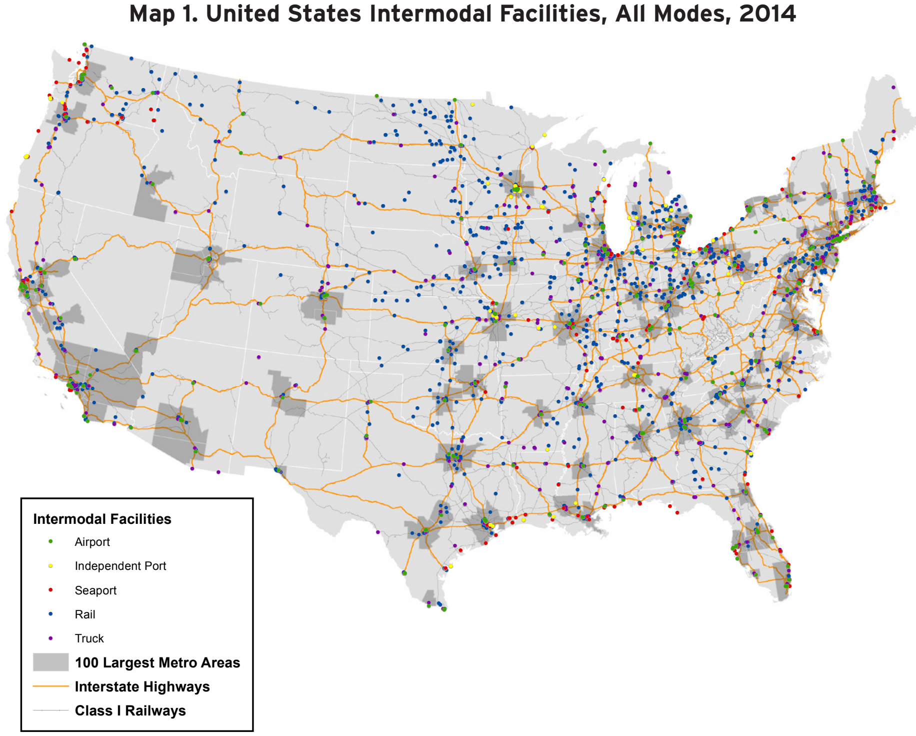
With the expansion of global trade, standardized shipping containers have become an increasingly important way to seamlessly move goods between distant markets across long supply chains. To meet these demands, intermodal transportation—or the movement of standardized containers by more than one transportation mode—saw loading operations grow by 60 percent between 2000 and 2014.[44] Much of this activity takes place in the rail sector, where intermodal carloads now represent upwards of 40 percent of all rail volume.[45] In particular, rail growth is most prevalent in the Midwest and East, where nearly all states experienced at least 5 percent growth in intermodal carloads between 2007 and 2012.[46] By accessing these facilities, firms are able to increase their productivity and spread economic benefits to all consumers nationwide.[47]

Based on the rapid growth in intermodal freight, the country now maintains an inventory of over 3,200 unique intermodal facilities, covering every corner of the country and representing the full breadth of modal specialties.[48] Moreover, more than 60 percent of these facilities (2,020) are located in the 100 largest metro areas. These include 80 percent of all aviation-based intermodal facilities and an above-average amount of rail facilities. Meanwhile, smaller metro areas and rural areas still house over 1,200 facilities, most of them focusing on bulk commodities or serving as key exchange points between major markets.

The intermodal clustering in large markets is especially clear in logistics centers. For example, Chicago is home to 141 facilities, making it the only metro area to exceed 100 facilities and reaffirming its tradition as the county's central freight hub. Another eight metro areas—including New York, Kansas City, Mo., and Los Angeles—maintain over 50 intermodal facilities. Other metro areas with demonstrated modal specialties—aviation in Miami or seaborne trade in Houston—tend to have large numbers of related intermodal facilities.

Unfortunately, limitations of current freight surveys make it difficult to accurately track intermodal flows between regions.[49] The Metro Freight series' database includes a multiple modes category, which is referenced throughout the report. However, that category captures more than just intermodal container moves—it also includes noncontainerized transfers like bulk products and physical goods moved by parcel. In the future, improved regional surveys of intermodal freight flows could help researchers and policymakers better understand how these facilities connect the country's regional economies.

Map 1. United States Intermodal Facilities, All Modes, 2014

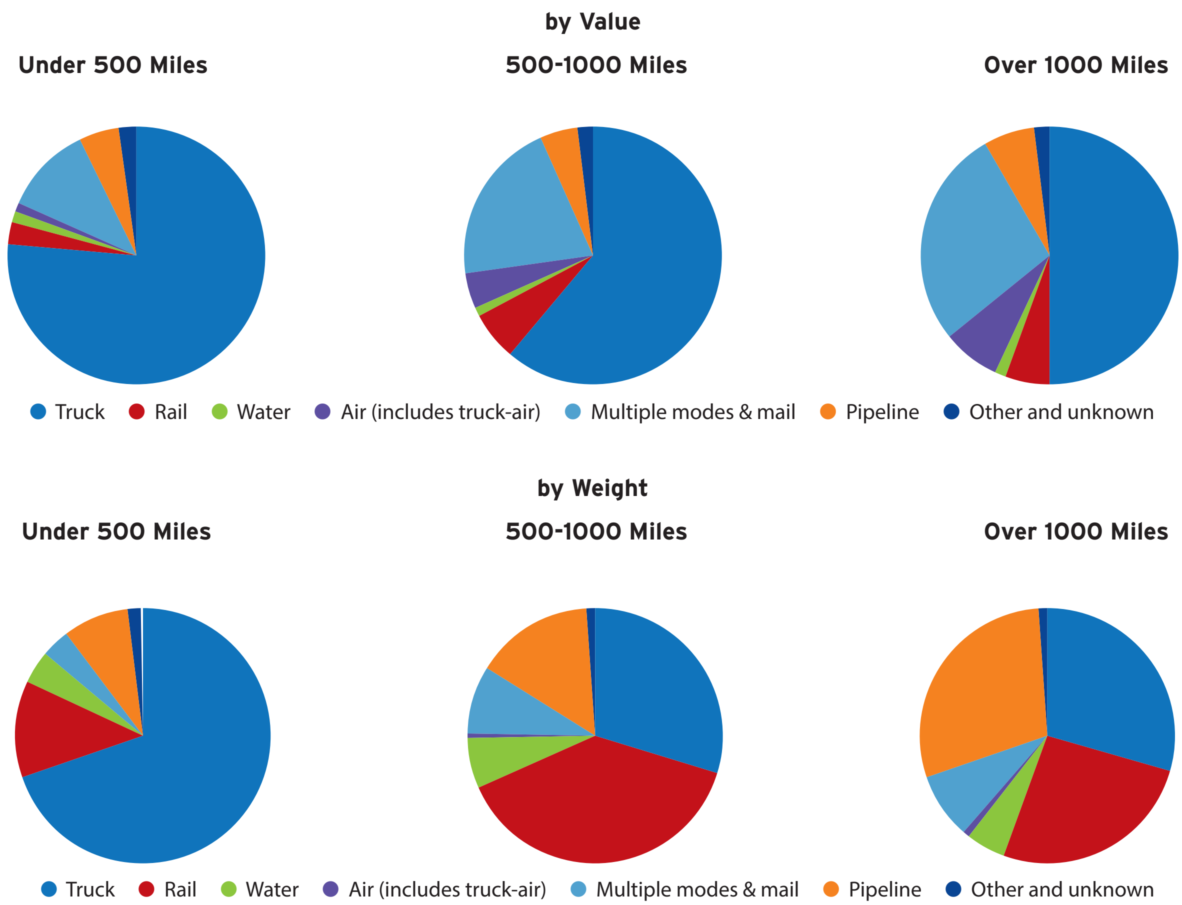


Source: Bureau of Transportation Statistics data

Neighboring metropolitan areas can depend on trucks for 90 percent or more of their freight activity, heavily influencing their infrastructure needs.

From bustling parts of New York and Los Angeles to rural expanses of Iowa and Nebraska, major trade corridors across the country frequently vary in the types of products shipped and modes used every day. Metro areas trade more goods between one another the shorter the distance—each additional 100 miles separating two regions reduces expected trade volumes by 3.2 percent—and they tend to rely on trucks the most to carry out these exchanges. Indeed, trucks move nearly three-quarters of all goods transported under 500 miles and 84 percent of goods under 100 miles, both by value and weight (Figure 5).[50] In contrast, multiple modes, railroads, and pipelines largely concentrate on shipping goods up to 1,000 miles or even farther depending on the specific commodity.

Figure 5. Share of Total Trade by Mode and Distance



Source: Brookings analysis of EDR data

Since many of the country's largest trade corridors stretch between neighboring metro areas, highways often dominate these movements and infrastructure needs. For example, trucks carry 75 percent ($49 billion) of the freight between Philadelphia and New York and more than 80 percent ($36 billion) between San Diego and Los Angeles. The same proves true for several other sizable, geographically proximate corridors across the country, such as Portland, Ore. and Seattle (81 percent) in the Northwest, Kansas City and St. Louis (88 percent) in the Midwest, and Tampa and Orlando, Fla. (93 percent) in the Southeast.

Table 3. 10 Largest Metropolitan Trade Corridors via Truck and Air Modes, by Value ($ millions) and Distance (miles), 2010*

Rank	Trader A	Trader B	Value Moved by Trucks	Total Value	Share of Total Value	Distance
1	Philadelphia-Camden-Wilmington	New York-Northern New Jersey-Long Island	$49,935.1	$66,392.7	75.2%	96.7
2	San Diego-Carlsbad-San Marcos	Los Angeles-Long Beach-Santa Ana	$35,503.4	$44,303.6	80.1%	110.4
3	San Jose-Sunnyvale-Santa Clara	San Francisco-Oakland-Fremont	$33,049.5	$40,568.0	81.5%	77.4
4	Riverside-San Bernardino-Ontario	Los Angeles-Long Beach-Santa Ana	$23,695.4	$55,378.8	42.8%	120.8
5	Dallas-Fort Worth-Arlington	Houston-Baytown-Sugar Land	$23,290.4	$28,207.8	82.6%	231.4
6	New York-Northern New Jersey-Long Island	Los Angeles-Long Beach-Santa Ana	$22,390.7	$37,366.6	59.9%	2,445.4
7	Phoenix-Mesa-Scottsdale	Los Angeles-Long Beach-Santa Ana	$20,171.6	$26,784.2	75.3%	356.9
8	San Jose-Sunnyvale-Santa Clara	Los Angeles-Long Beach-Santa Ana	$20,058.1	$33,696.0	59.5%	263.8
9	Boston-Cambridge-Quincy	New York-Northern New Jersey-Long Island	$19,743.0	$25,200.0	78.3%	190.4
10	Washington-Arlington-Alexandria	Baltimore-Towson	$19,567.3	$21,064.5	92.9%	54.9

Rank	Trader A	Trader B	Value Moved by Air	Total Value	Share of Total Value	Distance
1	San Jose-Sunnyvale-Santa Clara	Anchorage	$9,636.1	$9,688.1	99.5%	2,120.0
2	Los Angeles-Long Beach-Santa Ana	Anchorage	$6,774.3	$8,216.0	82.5%	2,371.8
3	Chicago-Naperville-Joliet	New York-Northern New Jersey-Long Island	$6,452.0	$32,849.4	19.6%	726.5
4	San Jose-Sunnyvale-Santa Clara	Los Angeles-Long Beach-Santa Ana	$5,852.1	$33,696.0	17.4%	263.8
5	Los Angeles-Long Beach-Santa Ana	San Francisco-Oakland-Fremont	$5,233.7	$24,991.3	20.9%	341.0
6	Phoenix-Mesa-Scottsdale	Seattle-Tacoma-Bellevue	$5,173.5	$7,327.1	70.6%	1,116.4
7	New York-Northern New Jersey-Long Island	Anchorage	$4,979.7	$5,150.9	96.7%	3,335.5
8	Chicago-Naperville-Joliet	Anchorage	$4,112.7	$4,427.0	92.9%	2,832.1
9	Dallas-Fort Worth-Arlington	New York-Northern New Jersey-Long Island	$3,823.4	$16,017.5	23.9%	1,380.9
10	San Francisco-Oakland-Fremont	Anchorage	$3,629.0	$4,006.4	90.6%	2,045.0

**Note that neither table displays duplicated trade corridors (e.g. Philadelphia-New York, New York-Philadelphia) or corridors within the same metro area (e.g. New York-New York), which appear for some port-related flows*
Source: Brookings analysis of EDR data

Trucks are especially significant along shorter trade corridors that exchange complementary types of goods in well-defined industry clusters.[51] For instance, Youngstown and Pittsburgh, Pa. (metals), Stockton and Fresno, Calif. (agricultural products), and Greenville and Spartanburg, S.C. (tools/manufacturing products) are each about 100 miles apart and move up to 97 percent of their goods by truck. Several areas also primarily rely on trucks to connect to nearby regional hubs for the widespread distribution of their products; these include Colorado Springs and Denver, Colo. (96 percent), Chattanooga, Tenn. and Atlanta (95 percent), and Manchester, N.H. and Boston (91 percent). In many cases, machinery, electronics, and mixed freight fill trucks along these routes, supplying producers and consumers with needed materials in extensive value chains.

Over longer distances and other types of industries, however, a wide variety of modes are usually responsible for channeling goods into different markets. As Table 3 illustrates, many of the biggest

Table 4. 10 Largest Metropolitan Trade Corridors for Railroads and Pipelines, by Weight (thousands of tons) and Distance (miles), 2010*

Rank	Trader A	Trader B	Weight Moved by Railroads	Total Weight	Share of Total Weight	Distance
1	Rest of Wyoming	Rest of Texas	41,781.0	42,701.2	97.8%	912.1
2	Rest of Illinois	Rest of Wyoming	32,145.4	32,629.5	98.5%	968.0
3	Rest of Wyoming	St. Louis	30,349.1	34,835.8	87.1%	942.8
4	Rest of Kansas	Rest of Wyoming	24,552.8	25,140.1	97.7%	571.7
5	Rest of Oklahoma	Rest of Wyoming	20,309.9	20,852.6	97.4%	740.8
6	Rest of Iowa	Rest of Wyoming	17,651.3	17,903.8	98.6%	716.9
7	Rest of Arkansas	Rest of Wyoming	14,154.6	14,444.9	98.0%	983.2
8	Rest of Wyoming	Kansas City	13,976.1	14,254.0	98.1%	735.6
9	Rest of Wyoming	Chicago-Naperville-Joliet	13,902.0	16,170.5	86.0%	1,006.4
10	Rest of Missouri	Rest of Wyoming	13,514.7	15,048.4	89.8%	850.1
Rank	**Trader A**	**Trader B**	**Weight Moved by Pipelines**	**Total Weight**	**Share of Total Weight**	**Distance**
1	Rest of Texas	Houston-Baytown-Sugar Land	32,304.2	74,099.7	43.6%	265.7
2	Riverside-San Bernardino-Ontario	Los Angeles-Long Beach-Santa Ana	25,955.7	47,236.1	54.9%	120.8
3	Baton Rouge	New Orleans-Metairie-Kenner	25,312.1	37,612.2	67.3%	102.1
4	Rest of Texas	Corpus Christi	15,854.8	24,154.6	65.6%	275.0
5	Oxnard-Thousand Oaks-Ventura	Los Angeles-Long Beach-Santa Ana	12,311.2	25,581.4	48.1%	56.6
6	Beaumont-Port Arthur	Houston-Baytown-Sugar Land	11,656.4	35,146.1	33.2%	70.8
7	Houston-Baytown-Sugar Land	Chicago-Naperville-Joliet	11,577.4	17,442.6	66.4%	929.7
8	Philadelphia-Camden-Wilmington	New York-Northern New Jersey-Long Island	10,888.5	38,993.8	27.9%	96.7
9	Baton Rouge	Rest of Louisiana	9,577.0	23,158.2	41.4%	62.3
10	St. Louis	Chicago-Naperville-Joliet	9,022.4	17,635.9	51.2%	256.4

**Note that neither table displays duplicated trade corridors (e.g. Philadelphia-New York, New York-Philadelphia) or corridors within the same metro area (e.g. New York-New York), which appear for some port-related flows*
Source: Brookings analysis of EDR data

trade corridors by total volume still rely on trucks, yet the shares are considerably lower for places like New York and Los Angeles (60 percent) that transport goods across thousands of miles. At the same time, specific types of commodities can heavily influence these exchanges, as is the case between San Jose and Los Angeles, Calif., which transport more than $4.5 billion in electronics between each other and often use multiple modes instead.

Finally, this modal variety plays out across vast distances and for heavier goods in many nonmetro areas (Table 4). Rural parts of Wyoming, for instance, transport over 500 million tons of energy products annually, making up 93 percent of all their trade and causing them to overwhelmingly rely on railroads to reach Texas, Illinois, and several other parts of the country. In addition, the experience of Houston, Baton Rouge, La., and similar refinery centers along the Gulf Coast reveals how pipelines, filled with different chemicals and petroleum byproducts, can carry nearly two-thirds of the total tonnage between regions.

Implications

To facilitate trade between markets near and far, the United States relies on a full suite of freight transportation modes to maintain economic competitiveness. Trucks anchor the national system, offering flexible service and storage capacity across thousands of road and highway miles. Over 70 percent of all goods move exclusively by truck, and trading partners separated by short distances are even more likely to use trucks. Depending on the specific commodity, however, several other freight modes play an essential role in regions as well. A mix of aviation and multiple modes, for instance, transports many of the advanced industrial products that power metro economies. Likewise, railroads and pipelines concentrate on moving heavy products over longer distances, especially throughout rural America.

The result of these varied modal responsibilities is a complex but complementary system of freight movements—one that depends on a specific set of assets within the larger infrastructure network. While the country boasts over 160,000 miles in the National Highway System, only 5 percent of U.S. roads handle 75 percent of all truck traffic.[52] The vast majority of rail traffic travels on the minority of mileage classified as primary rail corridors.[53] At the same time, only 25 metropolitan areas handle 85 percent of all international trade flows, making infrastructure inside and outside these port facilities especially important for global competeiveness.[54]

All of these flows tend to concentrate in the country's largest metro areas. The 100 largest metro areas not only house most producers and consumers, but they also stand at the intersection of most major highways and railroads, leading to outsized shares of logistics-related employment, warehousing operations, and intermodal container facilities.[55] As a result, the transportation congestion and constrained land development in these dense urban environments will create transportation-related costs that affect all freight flows—no matter their origin or destination.[56]

Freight policies must begin to recognize how certain places and infrastructure assets are central to the national freight network. Doing so will require targeted reforms at all levels of government, in addition to more frequently updated, geographically granular metrics as showcased in this report.

Federally, legislators and their executive branch colleagues should design a multimodal policy framework that maintains connectivity and prioritizes new capacity in nationally significant places.[57] The previous era of surface transportation policies built a world-class highway network, and trucking's share of freight flows proves the value of that investment. A reformed surface program, however, should work with states to prioritize maintenance of those assets based on clearer formulas and economic criteria, including the value and tonnage of interstate goods as well as the total international value and tonnage moved at statewide ports.[58] The remaining funding—whether through traditional sources like the gas tax or new freight-based revenues—should support competitive, multimodal programs that reward metro areas and rural locations that move the most goods and have specific infrastructure needs. Broad qualification is critical in this respect, since congestion at an airport, seaport, or railroad crossing can stall the free flow of goods as much as a highway pinch-point, as has recently been the case at West Coast ports.[59]

As the primary builders and operators of public freight infrastructure, states should follow a similar approach. That process begins with the development of state freight plans, outlined in MAP-21, that can help galvanize additional public- and private-sector investments. By assessing how freight moves in, out, and within states, particularly in terms of specific commodities and industries, these efforts can better target spending on projects of economic significance, especially those related to growing industries. The expansion of multistate planning with regional neighbors can improve investment coordination, especially among those states that conduct heavy trade with one another and whose logistical problems may directly spill over. State freight plans should also set clear long-term priorities and a more accurate accounting of performance measures based on relevant costs and benefits. An overarching goal, then, is to overcome some of the documented failings within the Statewide Transportation Improvement Program (STIP), which often lacks transparency and may over-promote projects based on political concerns.[60]

Likewise, local governments should engage in a new form of freight planning that is more regional in scope and recognizes place-specific concerns within larger infrastructure networks. For example, localities can craft land use regulations and policies that are more conducive to moving goods efficiently in and out of business and warehousing centers. Mapping which industries produce and consume the most goods—and then tracking their projected growth over time—offers one way localities can gauge these freight needs. Atlanta and Seattle are among the areas that have pursued similar strategies, locating the most goods-intensive industries in lower-density corridors, where freight can move in and out at peak efficiency.[61] For dense urban locations, heavy-truck regulations on local streets, specified delivery times, and other related policies can also help mitigate congestion.

Conclusion

As the United States transports more goods domestically and internationally over time, public and private leaders at all levels must work in tandem to design, build, and maintain a more efficient freight infrastructure network. Although trucks continue to represent the most important transportation mode nationally, moving almost 70 percent of all U.S. goods, regions across the country depend on a variety of modes to connect their economies. In the face of rising congestion and other budget pressures, these regions are facing a laundry list of freight challenges to address, making it all the more essential that they create more targeted plans and investments.

Understanding how different transportation modes support regional economies marks a significant step in this respect. The fact that the country's largest metropolitan areas rely on aviation and multiple modes to carry their most innovative, valuable products illustrates how existing transportation policies must connect more directly to larger economic priorities. The same proves true for many of the country's nonmetropolitan areas, which often rely on railroads, pipelines, and waterways to carry their raw, bulk commodities. Beyond highways, then, policymakers at the federal, state, and local level must embrace a multimodal perspective when it comes to freight, viewing different modes—and intermodal facilities—as part of an integrated network.

Given the highly interconnected nature of the country's trade network—with over 77 percent of goods crossing state lines—the federal government has a fundamental role to play in this process by providing stronger leadership and steering freight investments into places with particular infrastructure needs. States, meanwhile, will need to continue to develop clearer freight plans and better prioritize projects in support of long-term economic goals. Localities, including local planning agencies and private firms, need to work more closely together at a regional scale to streamline the movement of goods.

Through this comprehensive approach, policymakers can better articulate the country's regional freight needs and launch investments more strategically in support of long-lasting economic growth.

Appendix A: Study design

Goods trade database

This report uses a unique database measuring goods traded among U.S. metropolitan areas, nonmetropolitan regions, and international geographies. We used the data foundation and design scheme of the publicly available Freight Analysis Framework (FAF), Version 3.2. The U.S. Federal Highway Administration (FHWA) constructed the database with the help of the Oak Ridge National Laboratory (ORNL).[62] The database provides a comprehensive view of freight movement to, from, and within the United States. Originally based on calendar year 2007, Version 3.2 has been provisionally updated to estimate 2010 total freight volumes, or flows, by annual tonnage, value, and ton-mileage.

FAF estimates and assigns these flows through a matrix based on the shipment origin (O), shipment destination (D), commodity being transported (C), and mode used (M). To build this matrix and model freight movement, FAF draws from multiple data sources, but is principally derived from the Commodity Flow Survey (CFS), which is conducted every five years through a partnership between the U.S. Census Bureau and the Bureau of Transportation Statistics (BTS) as part of the Economic Census.[63] The CFS is a shipper-based survey that tracks the number of tons and dollar value of goods transported annually across all modes between different regions of the United States. However, because the CFS excludes imports and collects limited data for several freight-related industries, FAF uses a multistep approach and additional data sources to estimate these "out-of-scope" flows.

In total, the FAF matrix covers 131 geographic regions, 43 commodities, and seven transportation modes. Geographically, FAF's origin-to-destination (O-D) movements span 123 domestic regions and eight world regions, including 74 state-specific U.S. metropolitan areas, 33 state remainders, and 16 whole states. Metropolitan areas in FAF do not cross state lines, meaning metropolitan statistical areas are frequently divided into different parts depending on the states located within their respective bounds. Kansas City, for instance, is divided between two states (Missouri and Kansas). In addition, FAF does not follow a single metropolitan geographic definition, and instead uses both Combined Statistical Area (CSA) and Core Based Statistical Area (CBSA) definitions. For international flows, Canada, Mexico, and six groups of multiple other countries are included and classified in the same way as statistical regions by the United Nations.[64] Despite FAF's extensive spatial scope, it often lacks granularity for specific metro areas and even for most country-level origins and destinations.

FAF reports commodities at the Standard Classification of Transported Goods (SCTG) system's two-digit level. Collectively, there are 43 different two-digit SCTG commodity codes, ranging from live animals and fish (SCTG-01) to logs (SCTG-25) and mixed freight (SCTG-43). FAF relies on a variety of data sources to estimate these commodity flows because many goods, including agricultural and petroleum products, are concentrated in industries that fall outside the scope of the CFS.

By partnering with Economic Development Research Group (EDR), we were able to modify FAF to create a new database that identifies commodity flows with greater domestic and international precision. In addition to industry data from IMPLAN and Moody's Analytics, trade data from the World Institute for Strategic Economic Research (WISER) were particularly important to help model freight movement in terms of local economic activity. While carrying out this work, we also addressed several gaps and discrepancies inherent in FAF.

With an interest in showing domestic and international freight flows in, out, and among all of the country's metropolitan areas, we worked with EDR to estimate freight movement across combined statistical areas (CBSAs). Because FAF zones and CBSAs have overlapping spatial coverage at the county level, we first allocated FAF zone flows down to individual counties and then aggregated up to larger CBSAs. To accomplish this task, we used appropriate production, consumption, and port flow data when allocating totals—in both dollars and tonnage—to specific domestic origins and destinations.

Domestically, the estimation process varied slightly depending on the exact geography, mode, and type of flow in question. For example, we assigned flows between two distinct metropolitan areas on the basis of the magnitude of production and consumption in each area, while we used an additional gravity constraint when estimating flows that involved large FAF zones (such as state remainders) to match supply and demand over longer distances. A gravity constraint is a way to use distance alongside economic data when determining trade flows between places.

In all domestic regions, the estimation process followed three essential steps: (1) allocate the commodity supply on the basis of the county share of industries producing this commodity; (2) allocate the commodity demand on the basis of the county share of industries consuming this commodity; and (3) balance the commodity production and attraction on the basis of modal availability. We then aggregated these county commodity flows in turn to their respective CBSAs, while approximating the original FAF aggregate totals for the particular commodity. We classified remaining flows not included in the CBSAs under state remainders.

Internationally, the estimation process relied more extensively on a domestic gravity constraint to allocate export and import flows, primarily because of commodity sourcing issues in FAF. Because FAF defines international movement in two ways—separating the domestic and international legs—there was a statistical concern regarding port-related metros over-assigned local production and consumption trade flows. Miami, for instance, not only served as an enormous port for moving exports out of the country, but FAF also recorded it as one of the largest producers (or origins) for these exports. Anchorage, likewise, served as a primary port of entry for imports, but it was designated one of the largest consumers (or final destinations) for these imports. Our new database, by contrast, used WISER trade data and an additional gravity constraint to link the origin for exports and destination for imports more directly in terms of patterns of economic production and consumption. The results are a relative match for past Metropolitan Policy Program export research, sharing a 0.91 correlation with ExportNation's 2010 goods data.[65] However, because this report and ExportNation use different statistical bases, and only ExportNation includes service exports, the actual numbers will not match between the two datasets.

Among commodities that fall outside the scope of the CFS, crude petroleum (SCTG 16) required particular additional attention. Limited by the sample size for this commodity—along with numerous industry records suppressed for confidentiality—FAF relies on a variety of sources to estimate petroleum flows by value and weight at the county level. To address such gaps, our database allocates these missing flows to counties with nonsuppressed refinery data.

In summary, our new database uses the same design as FAF but adds geographic granularity and increased data certainty. It still includes all 43 two-digit SCTG commodities and seven transportation modes, described in the box below.[66]

TRANSPORTATION MODES[67]

Truck: includes private and for-hire trucks. Private trucks are owned or operated by shippers, and exclude personal use vehicles hauling over-the-counter purchases from retail establishments.

Rail: includes common carriers and private railroads, encompassing a range of Class I, II, and III companies.

Water: includes inland and intracoastal waterway movements. Shallow draft, deep draft, and Great Lakes shipments are also counted in this modal category.

Air (includes truck-air): includes shipments typically weighing more than 100 pounds that move by air or a combination of truck and air in commercial or private aircraft. Also includes air freight and air express.

Pipeline: primarily includes energy shipments via oil pipelines as well as flows from offshore wells to land.

Multiple modes and mail: includes truck-rail, truck-water, and rail-water intermodal shipments involving one or more end-to-end transfers of cargo between two different modes. It is not limited to containerized cargo, and also includes parcel delivery services.

Other and unknown: includes miscellaneous and other types of transportation.

Table A1. International Geographies Included in Brookings Goods Trade Database

Foreign Geography	Geography Type
Argentina	Country
Brazil	Country
Canada	Country
Chile	Country
China	Country
Colombia	Country
France	Country
Germany	Country
India	Country
Japan	Country
Republic of Korea	Country
Mexico	Country
Netherlands	Country
Singapore	Country
South Africa	Country
Spain	Country
Turkey	Country
United Kingdom	Country
Western Africa	Country Group
Eastern Africa	Country Group
Northern Africa	Country Group
Middle Africa	Country Group
Caribbean	Country Group
Australia and New Zealand	Country Group
Melanesia	Country Group
Micronesia	Country Group
Polynesia	Country Group
Central Asia	Country Group
Eastern Europe	Country Group
Remainder of South America	Rest Of Group
Remainder of Central America	Rest Of Group
Remainder of Southern Africa	Rest Of Group
Remainder of North America	Rest Of Group
Remainder of Eastern Asia	Rest Of Group
Remainder of Southern Asia	Rest Of Group
Remainder of South-Eastern Asia	Rest Of Group
Remainder of Southern Europe	Rest Of Group
Remainder of Western Asia	Rest Of Group
Remainder of Northern Europe	Rest Of Group
Remainder of Western Europe	Rest Of Group

Source: Brookings Institution and Economic Development Research Group

Geographically, the database now includes 361 metropolitan areas, 48 state remainders, and 40 international geographies.[68] Table A1 lists the specific countries, country groups, and continental remainders.

Finally, the database and report analytics are only an estimation of expected goods trade and freight activity. While the CFS and FAF are based on an extensive survey of freight shippers—as is EDR's use of WISER's international shipping information—even the best surveys may over- or understate certain trade levels. Likewise, while EDR uses well-regarded gravity constraints and production and consumption data, these data modifiers can miss certain trading relationships. For example, the data modifiers have no method to purposely account for under-reported intrafirm trading relationships. These pitfalls are no different from other survey-based statistical analyses, but they are worth considering if certain trade levels or trading relationships appear off-base.

Time periods covered

Although FAF provides estimates of projected flows from 2007 through 2040, we include only 2010 provisional data in our database. Given the constantly changing nature of freight movement and other economic developments, it can be difficult to gauge these sudden—and sometimes lasting—fluctuations. Limitations and inconsistencies in existing freight data also make it challenging to track potential changes over time nationally, internationally, and between metro areas, most notably since FAF is the only subnational freight database and it precludes longitudinal comparisons. At the time of production, 2010 FAF estimates were the most current and comprehensive data available, which we adjusted to more precisely track commodity flows at the metropolitan scale. Future updates to our database would prove useful in monitoring freight movement changes over time, especially as the economy continues to emerge from the Great Recession.

Intermetropolitan flows, intrametropolitan flows, and port-related flows

The MetroFreight series has primarily focused on goods trade between metropolitan areas, meaning the geographic origin and destination are always different places. However, there is also a significant share of goods trade that occurs within metropolitan areas. Typically, an assessment of intrametropolitan goods trade would require a closer examination of several alternate trading dynamics and freight concerns.

When it comes to international flows, though, our goods trade database is similar to FAF by separating the movement of exports and imports at particular ports of exit and entry, respectively. These international flows, moreover, are available by the type of foreign transportation mode and domestic mode used at each regional port. For example, we are not only able to see how many international goods travel by water and air through port facilities in New York or Los Angeles, but we can also see how these goods travel to inland locations, whether by truck, rail, or multiple modes. The same proves true at major land border crossings, such as Detroit and Laredo. As with all international flows, we can observe commodity-specific movements at each port.

Despite this added level of international detail, we are not able to track where domestic flows pass through particular regions; we can only see the final domestic origin or destination. In this way, our goods trade database does not reveal the full range of goods that may be recirculated in inland hubs like Memphis or Louisville. Other economic measures, such as logistics employment, offer a better idea of how these regions fit into the country's larger freight network.

Industry connections and commodity groups

Goods trade volume and balances offer a useful way to gauge the profile of a metropolitan economy. By viewing commodities in light of the industries that "make" and "use" them, the following method allows us to assess this underlying relationship.

While partnering with EDR, we reviewed a series of input-output (I-O) tables, similar to those developed by the U.S. Bureau of Economic Analysis (BEA).[69] As defined by BEA, output (or make) tables show the production of commodities by industry, while input (or use/recipe) tables show the uses of commodities by intermediate and final users. Put simply, output tables illustrate the types of goods that different industries produce (in dollars), while input tables show the variety of goods used by these industries (also in dollars) to produce their final goods or services.[70] Furthermore, each industry features a unique "make share" and "use share" for specific commodities. Make shares depict the amount of a commodity that is produced per dollar of total output, and use shares depict the amount of a commodity required to produce every dollar of total output. In the furniture manufacturing industry, for instance, furniture products have a make share slightly less than 1, meaning that for every dollar of the industry's output, this commodity essentially represents the only final good produced. The same industry, though, commonly requires wood products to create this furniture, represented by a use share of less than 0.3. In other words, the industry uses 30 cents worth of wood products to create every dollar of output.

In many industries, there is a direct 1:1 relationship for particular commodities based on their make shares. Industries that specialize in automobile manufacturing, logging, or tobacco farming are among those that typically produce only one type of commodity. In contrast, there is often a one-to-many relationship for industries and commodities based on their use share, highlighting how industries frequently use different input commodities to create their output goods. In most cases, SCTG commodities such as base metals and machinery may account for only a fraction of a cent for every dollar of production. These commodities, in turn, are used as inputs in hundreds of industries, from steel manufacturers to electronics manufacturers.

With this background in mind, we analyzed the make-use shares for the 43 two-digit SCTG commodities across EDR's input-output matrix based on the North American Industry Classification System (NAICS). To manage the many industries that made products falling under multiple commodity codes, we created our own commodity classification system of 17 new commodity groups, shown in Table A2. This created a cleaner crosswalk between NAICS economic output data and SCTG commodity codes.

We were thereby able to clearly relate 107 "production-oriented" and 206 "service-oriented" four-digit NAICS industries to one of the 17 commodity groups. In short, the 107 production-oriented industries all had a make share for at least one commodity, while the remaining 206 service-oriented industries did not have a make share for any commodity. As a result, we classified production-oriented industries under 17 commodity groups, and created a 16th commodity group—for noncommodities—to classify service-oriented industries. While these service-oriented industries did not produce any physical goods, they did play an important role in using the 17 other commodities to provide their services, as based on their use shares.

After linking commodities with their respective NAICS industries, we were able to gauge how much production was linked to specific inputs and outputs across different metro areas. For each metro area, we downloaded 2010 GDP data from Moody's Analytics that applied to the four-digit industries included in our crosswalk. We then calculated the relative amount of production associated with each commodity on the basis of the industries linked to these goods, first in terms of output and later in terms of input.

There are two critical limitations to I-O tables and commodity crosswalks for this report's analytical approach. First, I-O tables do not capture household consumption patterns. Although I-O tables do

Table A2: Commodity Groups Included in Goods Trade Database

Commodity Name	Description	Relevant SCTG Codes
Agricultural Products	Includes various animal products, baked goods, and agricultural crops, ranging from fruits and vegetables to nuts and cereal grains. Also includes processed foods, tobacco products, and alcoholic beverages.	SCTG 01-09
Stones/Ores	Includes stone-related goods like gravel, a variety of non-metallic minerals like salt, and metal ores like iron.	SCTG 10-14
Energy Products	Includes coal and its related byproducts, oil products like crude petroleum and gasoline, and other liquefied fuels and oils.	SCTG 15-19
Chemicals/Plastics	Includes plastics, fertilizers, rubber, and a host of other organic and inorganic chemicals. Also includes pharmaceuticals and chemical mixtures for medical use.	SCTG 20-24
Wood Products	Includes logs, lumber, and other wood products, such as particle board. Also includes numerous paper products in the form of pulp, sheets, or printed materials.	SCTG 25-29
Textiles	Includes fabrics, yarns, and similar textiles used for clothing, carpets, and household furnishings. Also includes leather used for footwear, luggage, and other apparel.	SCTG 30
Metals	Includes base metals, such as steel, copper, and aluminum, in the form of bars, rods, and wire. Also includes ceramics, glass, and other cement mixtures.	SCTG 31-32
Machinery/Tools	Includes machines, parts, and gears used in a variety of mechanical equipment, such as engines, fans, and refrigerators. Also includes metal articles and tools, plus miscellaneous manufactured products like toys, clocks, and musical instruments.	SCTG 33-34, 40
Electronics	Includes a range of electrical components and equipment, from circuits and semiconductors to televisions and computers. Also includes communications equipment and transmission apparatus.	SCTG 35
Transportation Equipment	Includes parts and vehicles for automobiles, railroads, aircraft, ships, and other transportation equipment.	SCTG 36-37
Precision Instruments	Includes medical, scientific, and optical instruments, among other advanced surgical and navigational tools.	SCTG 38
Furniture	Includes household and office furniture, mattresses, medical furniture, and lighting fixtures.	SCTG 39
Waste/Scrap	Includes scrap and waste from wood, paper, glass, and metals.	SCTG 41
Mixed Freight	Includes miscellaneous food and supplies for offices and retail establishments, such as convenience stores and restaurants.	SCTG 43
Unknown	Includes goods not classified under any other commodity group.	SCTG 99

Source: Brookings Institution and Economic Development Research Group

show how much food or energy an industry may consume, they do not reference how much of similar products households may consume. In this sense, an I-O table cannot fully predict the aggregate level of commodity consumption taking place in a particular geography. Second, this report relied on a single I-O table for the entire country, and therefore does not capture variable industrial patterns by metropolitan area. Firms within the same industry will vary in the value of their inputs and outputs, meaning each metro should technically follow a unique I-O table based on its unique collection of firms and industry quality. This omission from our commodity-economic comparison will affect the results to an unknown degree and is an important area to improve in future research.

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65. This correlation compares the 361 metropolitan areas shared between the two datasets. The complete ExportNation dataset and research series is available at **www.brookings.edu/about/projects/state-metro-innovation/mei** (accessed July 2014).

66. Note that EDR's estimation process caused two SCTG commodities—mixed freight (SCTG 43) and commodity unknown (SCTG 99)—to be separated individually in domestic trade but not in international trade. However, they are still included in the international totals, collapsed with the other commodity groups.

67. This report uses the modal definitions included in the Freight Analysis Framework, available at **http://faf.ornl.gov/fafweb/Data/FAF3ODDoc611.pdf** (accessed April 2015). A separate modal category, "no domestic mode," is also included in the total trade volumes throughout this report, but are not analyzed separately in detail.

68. Due to statistical limitations, the following five metropolitan areas were not included in the database: Cape Girardeau-Jackson, MO-IL; Lake Havasu City-Kingman, AZ; Manhattan, KS; Mankato-North Mankato, MN; and Palm Coast, FL. All five were upgraded from micropolitan statistical areas to metropolitan statistical areas in the 2000s. Their trading relationships are added to the appropriate "remainder of state" totals.

69. For the full methodology of BEA tables, see **www.bea.gov/papers/pdf/IOmanual_092906.pdf** (accessed July 2014).

70. Note that goods can be simply consumed as well.

About The Global Cities Initiative

A Joint Project of Brookings and JPMorgan Chase

The Global Cities Initiative equips city and metropolitan area leaders with the practical knowledge, policy ideas, and connections they need to become more globally connected and competitive.

Combining Brookings' deep expertise in fact-based, metropolitan-focused research and JPMorgan Chase's market expertise and longstanding commitment to investing in cities, this initiative:

- Helps city and metropolitan leaders better leverage their global assets by unveiling their economic starting points on key indicators such as advanced manufacturing, exports, foreign direct investment, freight flow, and immigration.
- Provides metropolitan area leaders with proven, actionable ideas for how to expand the global reach of their economies, building on best practices and policy innovations from across the nation and around the world.
- Creates a network of U.S. and international cities interested in partnering together to advance global trade and commerce.

The Global Cities Initiative is chaired by Richard M. Daley, former mayor of Chicago and senior advisor to JPMorgan Chase. It is co-directed by Bruce Katz, Brookings vice president and co-director of the Brookings Metropolitan Policy Program, and Amy Liu, senior fellow and co-director of the Brookings Metropolitan Policy Program.

Launched in 2012, the Global Cities Initiative will catalyze a shift in economic development priorities and practices resulting in more globally connected metropolitan areas and more sustainable economic growth.

Core activities include:

Independent Research: Through research, the Global Cities Initiative will make the case that cities and metropolitan areas are the centers of global trade and commerce. Brookings will provide each of the largest 100 U.S. metropolitan areas with baseline data on its current global economic position so that metropolitan leaders can develop and implement more targeted strategies for global engagement and economic development.

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The Metropolitan Infrastructure Initiative was formed to develop timely independent analysis, frame key debates, and offer policy recommendations to help leaders in the United States and abroad address key infrastructure challenges. This and other publications, speeches, presentations, and commentary on infrastructure are available at: **http://www.brookings.edu/about/programs/metro/infrastructure-Initiative**.

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Trade and Logistics includes freight rail, air cargo operations, trucking, seaports/inland waterways, transportation support, and warehousing and express/local delivery services.

Energy includes the generation, transmission, and distribution of energy from natural gas (pipelines), facilities responsible for electricity (nuclear, hydroelectric, and solar/wind), and other utilities.

Water includes clean/drinking water, stormwater, wastewater, sewage/water treatment facilities, and "green" infrastructure critical to conserving related natural resources.

Telecommunications include broadband and transmission infrastructure (wired, wireless, and satellite), concentrated in facilities outside radio and television broadcasting.

Public Works include streetscapes, land redevelopment, and waste/landfills (solid waste, hazardous materials, and remediation).

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