An Economic Analysis of Spending on Marine Transportation System (MTS) Infrastructure

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U.S. Committee on the Marine Transportation System
CMTS

Report for the U.S. Committee on the Marine Transportation System prepared by Inforum at the University of Maryland

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EXECUTIVE SUMMARY

"Extensive and efficient infrastructure is critical for ensuring the effective functioning of the economy, as it is an important factor in determining the location of economic activity and the kinds of activities or sectors that can develop in a particular instance."

Schwab & Sala-i-Martín, 2012

This study, conducted by Inforum[1] for the U.S. Committee on the Marine Transportation System[2] (CMTS), provides a historical accounting of spending and performance of U.S. marine transportation system (MTS) infrastructure that is essential to the well-being and growth of the U.S. economy. The report provides evidence on the state of MTS infrastructure and offers data that indicate insufficient efforts to maintain and develop the system, leading to a deteriorating state of U.S. public infrastructure.

By leveraging available historical data and previous work concerning the economic costs of degraded infrastructure, this report considers how an increase in MTS infrastructure spending would affect economic performance. The analysis uses the Inforum LIFT model[3] to explore more robust funding levels for MTS infrastructure during a 26-year period spanning 2020 to 2045, including an 11-year capital investment program stretching from 2020 through 2030. This ultimately shows how infrastructure expenditure above current funding levels will help to recover from the long pattern of underspending in infrastructure, thus enabling higher growth, improved trade performance, expanded employment opportunities, and enhanced value of household incomes.

Importance of Marine Transportation System Infrastructure

Modern economies require substantial high-quality infrastructure to thrive. Such assets are indispensable for facilitating production in various industries, particularly goods-producing sectors such as agriculture, mining, and manufacturing. The ability to safely and efficiently move resources and final products through the nation's economic system, from mines, farms, and manufacturing facilities to consumers and business customers located far away, is crucial to American industry's long-term health and global competitiveness.

The U.S. Marine Transportation System (MTS) plays a leading role in providing these essential services to businesses, consumers, and

1 This research was performed by Inforum at the University of Maryland with the support of the U.S. Committee on the Marine Transportation System. The author is Ronald Horst, Ph.D. Questions may be directed to RHorst@umd.edu or 301-405-4636. More information about Inforum may be found in Appendix A and at www.Inforum.umd.edu.

2 The CMTS is a Federal Cabinet-level partnership of more than 25 Federal Government departments, agencies, and bureaus directed under statute to coordinate and recommend policies related to marine transportation. The CMTS is directed to (1) assess the adequacy of the MTS, including ports, waterways, channels, and their intermodal connections; (2) promote the integration of the MTS with other modes of transportation and other uses of the marine environment; and (3) coordinate, improve coordination and make recommendations regarding Federal policies that impact the MTS.

3 The LIFT model is a dynamic general equilibrium representation of the U.S. national economy. It combines an inter-industry input-output formulation with extensive use of regression analysis to employ a "bottom-up" approach to macroeconomic modeling. In this way, the model works like the actual economy, building the macroeconomic totals from details of industrial activity, rather than by distributing predetermined macroeconomic quantities among industries. More information about the LIFT model may be found at www.inforum.umd.edu.

governments. About 25,000 miles of navigable waterways allow American farmers, manufacturers, and other producers to compete in world markets by keeping transportation costs low. Inland waterways carry more than 600 million tons of cargo annually (ASCE, 2017). Commercial marine ports number approximately 360[4] providing essential links to foreign markets through which billions of tons of goods flow each year.

In 2017, major U.S. ports handled more than 873 million tons of domestic shipments and 1,512 million tons of international freight traffic (USACE, October 2018). These systems do not operate in isolation but instead rely on connections to road, rail, pipeline, and other transportation infrastructure. Despite the vital services these systems provide to the U.S. economy, many need long-overdue and substantial maintenance, repair, and modernization. The symptoms of decay are many, including lock shutdowns along U.S. waterways and unexpected delays that totaled approximately 144,000 hours in 2016, a 90 percent increase since 2000 (Bureau of Transportation Statistics, 2017).

Declining US Infrastructure

The World Economic Forum (WEF) names insufficient investment in productive factors, such as transportation infrastructure, as an important cause of the sluggish productivity growth that has slowed global economic expansion over the past decade. WEF publishes rankings of the factors of productivity and economic health for 141 countries (Schwab, 2019), identifying infrastructure as the second of 12 pillars of competitiveness. In 2018-2019, the United States was ranked second overall in competitiveness, trailing only Singapore. However, the transportation infrastructure in the US was ranked lower, at 12th among the 141 ranked nations. Its scores for connectivity for roads, airports, and water ports tended to be high, but measures of quality and efficiency were lower.

The American Society of Civil Engineers (ASCE) conducts a quadrennial qualitative national assessment of conditions and investment needs for major types of infrastructure, including land, water, and air transportation systems and utilities. According to the ASCE, the nation's infrastructure is in poor condition, with the overall grade of D+ in 2017, unchanged from the 2013 score. Inland waterways infrastructure also earned a D, while the grade for ports was slightly higher at a C+ (ASCE 2017). As our trading-partner nations continue to develop modern, efficient, and well-maintained infrastructure systems, the United States will face growing competitive pressures. Despite currently strong competitiveness in general, deficient infrastructure will make it increasingly difficult for domestic firms and workers to compete in world markets.

Recent data concerning U.S. public and private sector spending indicates a decline in real investment spending for many types of infrastructure[5]. Real, or "constant-price" investment[6], is the purchase of structures and equipment by government entities and private companies, where these assets provide key transportation and other services and where dollar values have been adjusted for inflation (in this case to 2009 or 2012 dollars). Real investment spending indicates the physical volume of infrastructure installed in each year. Many infrastructure spending declines stretch more than a decade, and resulting costs in time, wasted fuel, and vehicle maintenance continue to grow annually.

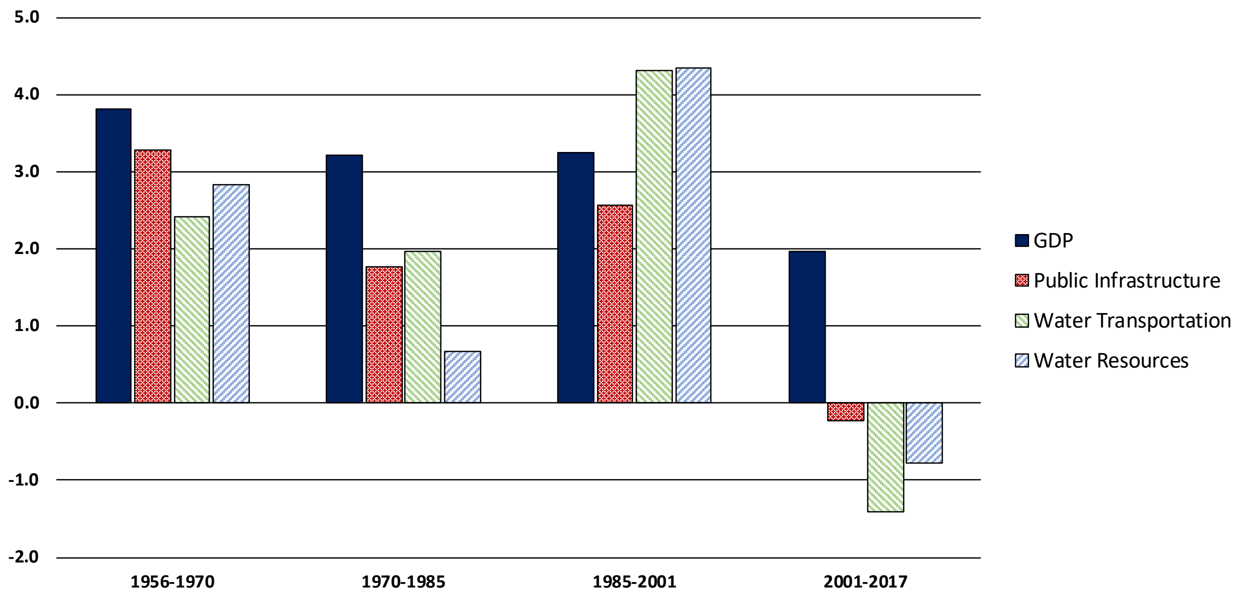
By re-igniting public and private investment in infrastructure, education, and innovation, countries not only would enhance productivity growth but also would foster additional employment and strengthen aggregate demand for goods and services.

4 According to the "2017 Transportation Facts & Information" published by the USACE, larger ports alone numbered 186 in 2017, with each handling at least 250,000 tons of freight, including 109 large coastal ports, 42 that serve traffic on the Great Lakes, and 35 inland ports. According to the U.S. Maritime Administration, in 2009 there were "approximately 360 commercial sea and river ports" ("America's Ports and Intermodal Transportation System," January 2009, www.glmri.org/downloads/Ports&IntermodalTransport.pdf).

5 See, for example, the Congressional Budget Office (October 2018).

6 A glossary of economic terms follows the report's conclusion.

Figure E-1. Real Public Infrastructure Expenditures (1956-2017)
Average Annual Percentage Growth Rates



Source: U.S. Congressional Budget Office (2018); U.S. Bureau of Economic Analysis, National Income and Product Accounts (October 2019); and authors' calculations.

Historic Infrastructure Investment

Recent trends in infrastructure investment reflect a mixed performance. Spending for some privately-owned infrastructure, such as freight rail and electric utilities, has been steady and relatively strong. On the other hand, spending for roads, maritime infrastructure, and many other types of public infrastructure has lagged, and with slower economic growth a likely consequence.

Figure E-1 shows the average annual growth of real (adjusted for inflation) GDP and real public infrastructure spending over four intervals, together with real spending growth for major components of MTS infrastructure. In the 46 years from 1956 through 2001, overall investment for public infrastructure[7] rose, at an average rate of about 1 percent lower than GDP growth. Between 2001 and 2017, GDP has grown more slowly on average, as real infrastructure spending contracted by 0.2 percent per year, lagging GDP growth by 2.2 percentage points. Between 1956 and 2001, investment in water transportation infrastructure (waterways, ports, vessels, and navigational systems) also increased, with growth exceeding 4 percent annually from 1985 to 2001. Spending on water resources infrastructure (dams, levees, reservoirs, and other assets) also surged in the 1980s and 1990s. However, real spending for both water transportation and water resources infrastructure has declined since 2001, with water transportation falling 1.4 percent per year and water resources contracting approximately 0.8 percent per year.

In this report, terms such as "Water Transportation" and "Water Resources" reflect concepts and data standards widely used by economists. In particular, economic data published by Bureau of Economic Analysis (BEA), Census Bureau, Congressional Budget Office (CBO), and other Agencies conform to these standards. These are related to the MTS concepts employed by CMTS and other agencies, but important differences exist. In this report, presentation and use of economic data and concepts will conform to the standards of the economics literature, while commentary on the

7 Public infrastructure included in these figures includes transportation infrastructure (highways, mass transit and rail, aviation, and water) and water infrastructure (water resources and water utilities) (CBO, 2018).

Table E-1. Real Public Infrastructure Expenditures, 2001-2017

	Billions of 2012$	Billions of 2012$	Average Annual Percentage Growth	Cumulative Percentage Change
	2001	2017	2001-2017	2001-2017
Real Gross Domestic Product	**13,262.1**	**18,108.1**	**2.0**	**36.5**
Public Infrastructure Spending	**419.5**	**404.3**	**-0.2**	**-3.6**
Capital	209.7	160.0	-1.7	-23.7
Operation and Maintenance	209.9	244.3	1.0	16.4
Water Transportation	11.8	9.4	-1.4	-20.4
Capital	6.9	3.4	-4.3	-50.7
Operation and Maintenance	4.9	6.0	1.2	21.6
Water Resources	29.9	26.4	-0.8	-11.7
Capital	13.4	7.4	-3.6	-44.7
Operation and Maintenance	16.6	19.0	0.9	14.5

Source: U.S. Congressional Budget Office (2018); U.S. Bureau of Economic Analysis, National Income and Product Accounts (October 2019); and authors' calculations.

broader subject will employ the MTS nomenclature.

Figure E-1 and Table E-1 data are from the CBO and BEA. MTS infrastructure is represented in the "Water Transportation" and "Water Resources" data categories.

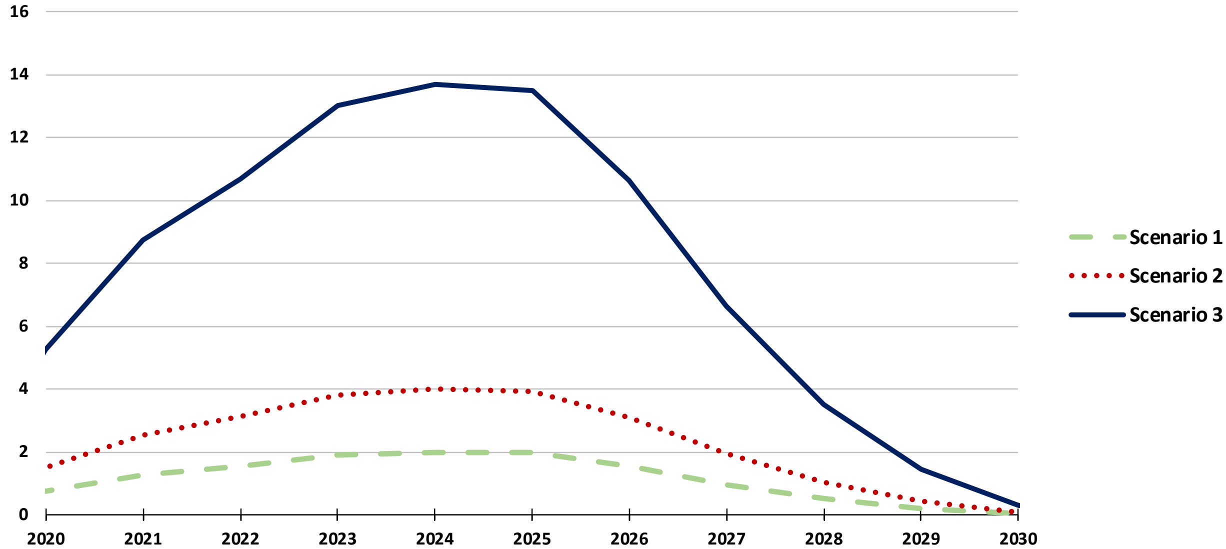
In contrast to most of the preceding 46 years, the volume of investment in the water transportation and water resources infrastructure categories contracted significantly from 2001 through 2017—with real spending on water transportation infrastructure contracting 1.4 percent annually. Table E-1 shows additional expenditure details for these components of infrastructure from 2001-2017, together with real GDP and overall public infrastructure spending. Each total spending figure is the sum of investment, or capital, spending and expenditure for operations and maintenance (O&M). The level of real expenditure for ports and inland waterways was 20.4 percent lower in 2017 than in 2001, with a dramatic decline in capital spending weighing heavily. Real expenditure for water resources was 11.7 percent lower in 2017 than in 2001. By 2017, capital spending for water resources, including dredging, plummeted 44.7 percent from 2001 levels.

Since the turn of the 21st century, escalating construction prices eroded effective investment because each dollar of Federal and state funding purchased relatively less infrastructure capital. Although construction inflation fell from previous highs, the volume of investment spending was far lower in 2017 than in 2001, due both to restrained nominal spending and higher construction prices. Budgets expanded more for O&M expenditure, and price growth for these activities was more subdued. Together, these imply real spending growth for O&M activities to be about 1 percent per year. The implication of these trends is a steady erosion of the Nation's essential MTS infrastructure base.

Benefits of Infrastructure Spending

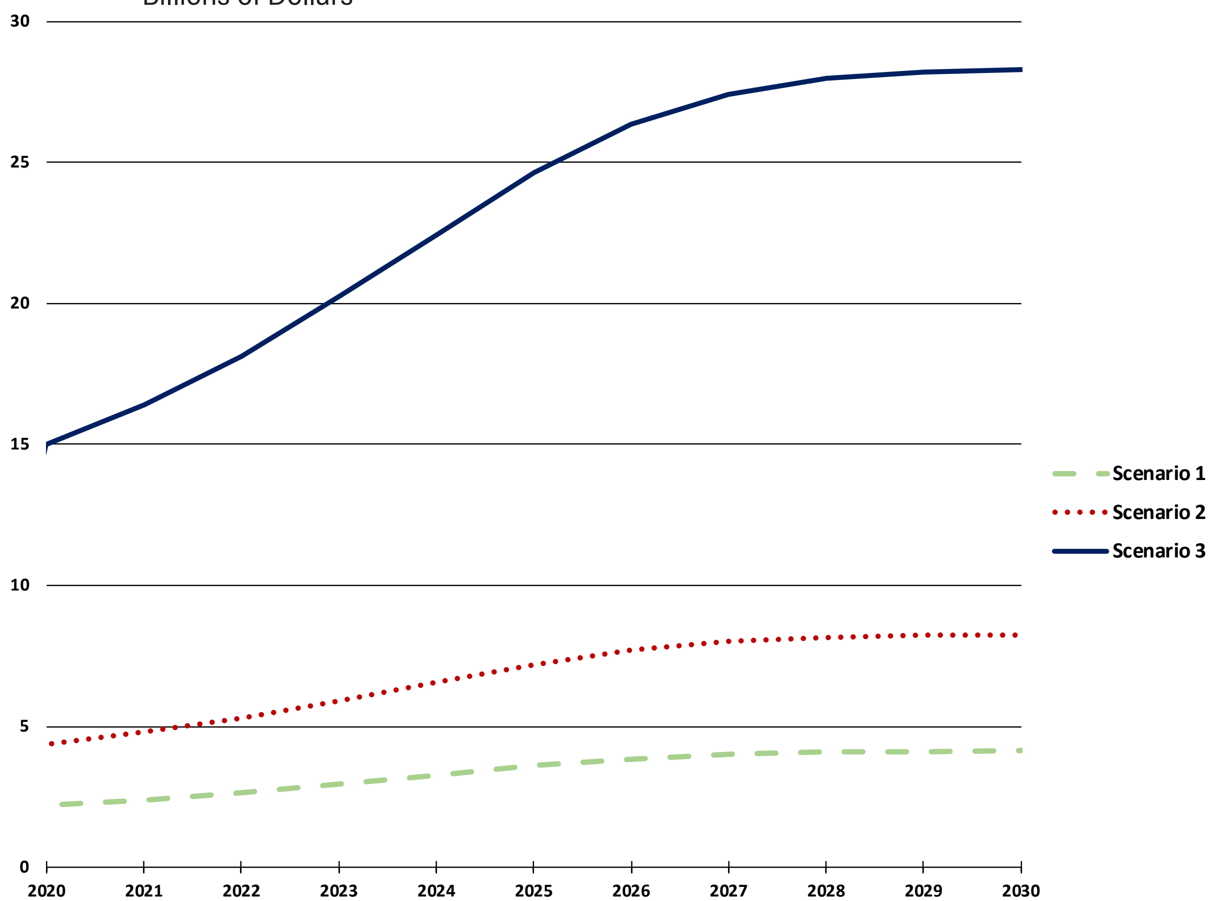
In the short run, spending on infrastructure stimulates aggregate demand that increases economic activity and creates jobs through direct, indirect, and induced demand impacts. However, the long-term benefits of infrastructure spending are even more significant and durable. Improvement of inland waterways and marine ports would boost international competitiveness—updated and well-maintained inland waterways and marine ports lower the cost of delivering goods both domestically and internationally by decreasing delays. The lower cost of imports reduces the cost of materials, positively affecting

Figure E-2. Nominal Investment Expenditure Enhancement (2020-2030)
Billions of Dollars



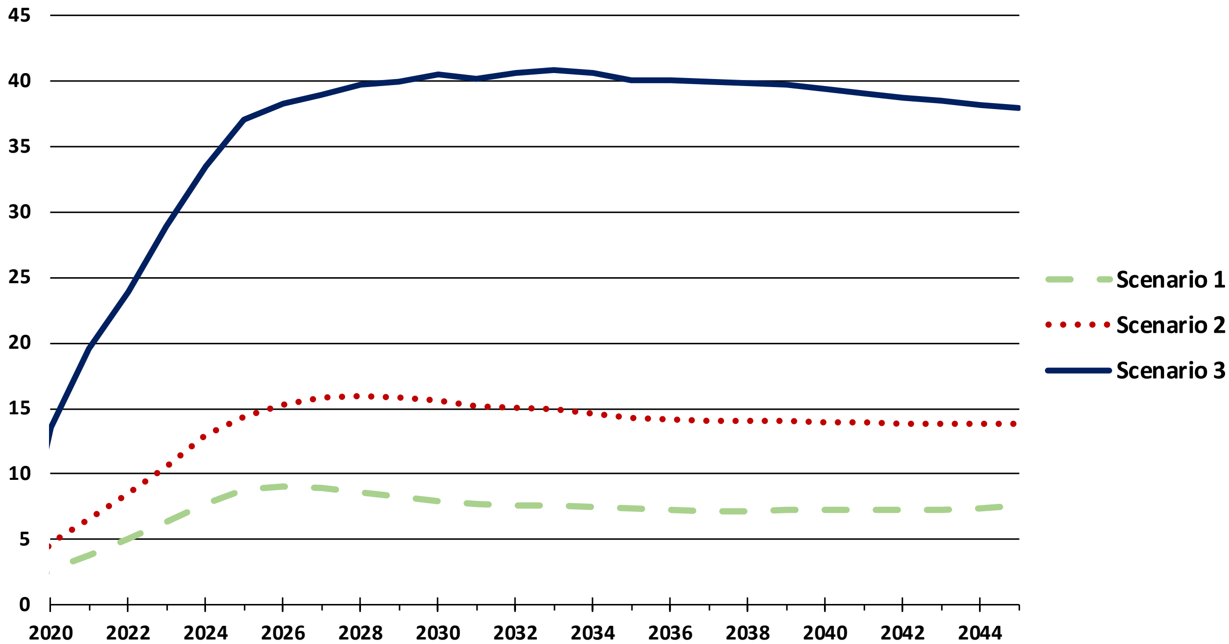
Source: Study assumptions.

Figure E-3. Nominal O&M Expenditure Enhancement (2020-2030)
Billions of Dollars



Source: Study assumptions.

Figure E-4. Effects of Enhanced Spending on Real GDP (2020-2045)
Billions of 2012$ Dollars



Source: Study assumptions.

both businesses and consumers through lower production costs and lower prices, while lower export costs help to boost our trade position in the international marketplace.

Scenarios and Baseline

The report contemplates three alternative potential efforts to improve MTS infrastructure spending. These scenarios range between $12 billion and $87 billion in additional capital spending from 2020 through 2030 (Figure E-2), with increases in O&M budgets ranging between $37 billion and $255 billion over the same period (Figure E-3).

Raising infrastructure expenditure by these amounts, as simulated using the LIFT model, illustrates how such enhanced spending can generate substantial long-term economic returns that significantly exceed their initial costs. A sustained multi-year investment boost for public infrastructure could be supported through a combination of funding sources—Federal, state, and local governments as well as the private sector. In the three scenarios, all entities responsible for supplying funding for public infrastructure make more significant commitments.

Findings

Compared to a baseline forecast that assumes continuation of limited public infrastructure investment that leads to reduced efficiencies and higher costs, the report finds the following:

- In the short term, enhancing the level of infrastructure spending would boost jobs by between 54.7 thousand and 182.5 thousand jobs in 2025, depending on the scenario; these numbers are shown in Table E-2. This number would fall over time as the productivity effects of better infrastructure take hold. As a result, the economy would improve meaningfully.
- By 2030, the level of real GDP would rise between about $8 billion and $41 billion in 2012 dollars (Figure E-4). Over the long term, competitiveness, output, and employment across industries would be enhanced thanks to the productivity-enhancing effects of better infrastructure. Increased productivity largely would be responsible for the higher GDP, but so would higher labor participation within a more dynamic economy.

Table E-2. Key Assumptions and Macroeconomic Results Summary (2020-2045)
Nominal Spending Assumptions, Real GDP, Employment, and Personal Income

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Assumed New Nominal Spending (Billions)										
Scenario 1	3.0	3.7	4.2	4.9	5.3	5.6	4.2	4.2	4.2	4.2
Scenario 2	5.9	7.3	8.4	9.7	10.6	11.1	8.3	8.3	8.3	8.3
Scenario 3	20.2	25.1	28.8	33.2	36.2	38.1	28.6	28.6	28.6	28.6
Gross Domestic Product (Billions 2012$)	**19,464.6**	**19,852.6**	**20,220.4**	**20,609.9**	**21,012.4**	**21,415.7**	**23,533.4**	**25,893.8**	**28,450.9**	**31,208.9**
	2.7	3.8	5.0	6.3	7.7	8.8	7.9	7.3	7.3	7.6
	4.7	6.6	8.5	10.6	12.9	14.4	15.6	14.2	14.0	13.9
	13.6	19.5	23.9	29.0	33.5	37.1	40.5	40.1	39.4	37.9
Personal Consumption Expenditures	**13,543.1**	**13,823.1**	**14,093.9**	**14,370.7**	**14,650.9**	**14,932.2**	**16,382.0**	**17,978.3**	**19,707.0**	**21,576.2**
	1.1	1.5	2.5	3.4	4.4	5.3	4.1	2.3	1.7	1.5
	1.2	1.9	3.1	4.4	5.7	6.8	7.6	4.3	2.9	1.8
	2.2	4.3	6.5	8.4	10.3	12.0	16.0	10.7	7.9	5.9
Gross private domestic investment	**3,534.3**	**3,642.3**	**3,743.4**	**3,854.2**	**3,975.7**	**4,099.0**	**4,764.3**	**5,516.7**	**6,341.6**	**7,297.7**
	0.7	1.4	1.7	2.0	2.5	2.7	1.8	2.1	1.9	1.8
	1.3	2.4	2.9	3.5	4.3	4.5	3.6	3.4	3.4	3.0
	3.0	6.7	7.9	9.5	11.0	11.7	9.4	10.2	10.2	8.9
Real Net Exports	**-967.6**	**-976.1**	**-986.8**	**-999.5**	**-1,015.5**	**-1,032.0**	**-1,108.4**	**-1,218.7**	**-1,323.6**	**-1,484.0**
	-0.8	-1.2	-1.6	-1.9	-2.2	-2.4	0.0	1.4	2.4	3.3
	-1.1	-1.9	-2.3	-2.8	-3.1	-3.2	0.4	3.6	5.4	7.3
	-3.0	-5.8	-7.1	-8.0	-8.3	-8.1	0.9	8.2	12.1	14.5
Government Consumption & Investment	**3,321.7**	**3,332.3**	**3,340.8**	**3,357.5**	**3,376.6**	**3,394.8**	**3,500.3**	**3,661.7**	**3,837.4**	**4,028.5**
	1.6	1.9	2.2	2.6	2.8	2.9	1.9	1.5	1.3	1.0
	3.1	3.9	4.5	5.1	5.5	5.8	3.9	3.1	2.6	2.1
	10.8	13.3	15.3	17.6	19.0	19.8	13.3	10.7	8.8	7.3
Total Jobs (Thousands)	**166,002.9**	**166,657.7**	**167,510.9**	**168,385.4**	**169,375.2**	**170,404.3**	**173,798.1**	**177,498.8**	**181,105.4**	**184,606.8**
	19.2	29.1	34.9	42.3	49.1	54.7	41.2	31.5	27.9	27.3
	31.5	48.3	59.0	70.8	82.6	90.9	71.5	49.6	45.5	45.0
	80.1	108.6	133.8	156.3	174.3	182.5	165.8	137.2	134.3	136.4
Unemployment Rate (Percent)	**3.76**	**4.17**	**4.33**	**4.58**	**4.73**	**4.60**	**4.61**	**4.61**	**4.60**	**4.60**
	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.00	-0.00	-0.00	0.00
	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.01	-0.00	-0.00	0.00
	-0.04	-0.05	-0.06	-0.06	-0.07	-0.06	-0.02	-0.00	0.00	0.00
Total Labor Productivity (2012$/Hour)	**70.377**	**71.343**	**72.335**	**73.376**	**74.408**	**75.419**	**81.265**	**87.611**	**94.478**	**101.832**
	0.002	0.000	0.002	0.003	0.004	0.005	0.003	0.004	0.006	0.008
	0.001	-0.000	0.001	0.003	0.004	0.005	0.007	0.010	0.013	0.015
	0.002	-0.001	-0.001	0.001	0.004	0.007	0.017	0.026	0.032	0.033
Disposable Personal Income (Billions)	**17,081.3**	**17,848.3**	**18,687.5**	**19,536.6**	**20,414.2**	**21,290.5**	**26,012.8**	**31,669.5**	**38,490.2**	**46,899.2**
	2.1	4.4	6.8	9.3	12.1	14.7	17.0	14.0	14.2	14.3
	3.9	7.8	11.9	16.3	21.2	25.2	30.2	25.1	25.5	26.3
	11.5	21.9	31.9	41.3	51.0	58.7	69.2	65.6	72.1	79.9
Real Disposable Income (Billions 2012$)	**15,204.0**	**15,537.0**	**15,908.3**	**16,280.4**	**16,643.6**	**16,978.9**	**18,569.8**	**20,271.5**	**22,110.8**	**24,175.2**
	1.3	2.8	4.5	6.2	8.0	9.6	11.1	10.5	12.2	15.4
	2.3	4.7	7.6	10.5	13.7	16.3	20.3	18.7	20.7	24.5
	6.5	12.9	20.3	27.5	34.2	39.7	49.9	49.4	54.2	60.8
Real Disposable Income per Household (2012$)	**116,972.6**	**118,469.6**	**120,233.3**	**121,972.5**	**123,603.9**	**124,998.6**	**131,216.6**	**138,295.1**	**146,499.4**	**156,329.6**
	10.4	21.2	33.7	46.1	59.4	70.7	78.5	71.6	80.9	99.4
	17.6	35.6	57.6	79.0	101.9	120.4	143.8	127.7	137.2	158.5
	49.8	98.5	153.7	205.7	253.8	292.4	352.7	336.7	358.8	393.0

Baseline levels are shown first in billions of 2012 dollars, billions of dollars, thousands of jobs, or in other units as noted. Results for Scenarios 1-3 are shown next as deviations from baseline, except where noted. *Source: LIFT Modeling Analysis by Inforum.*

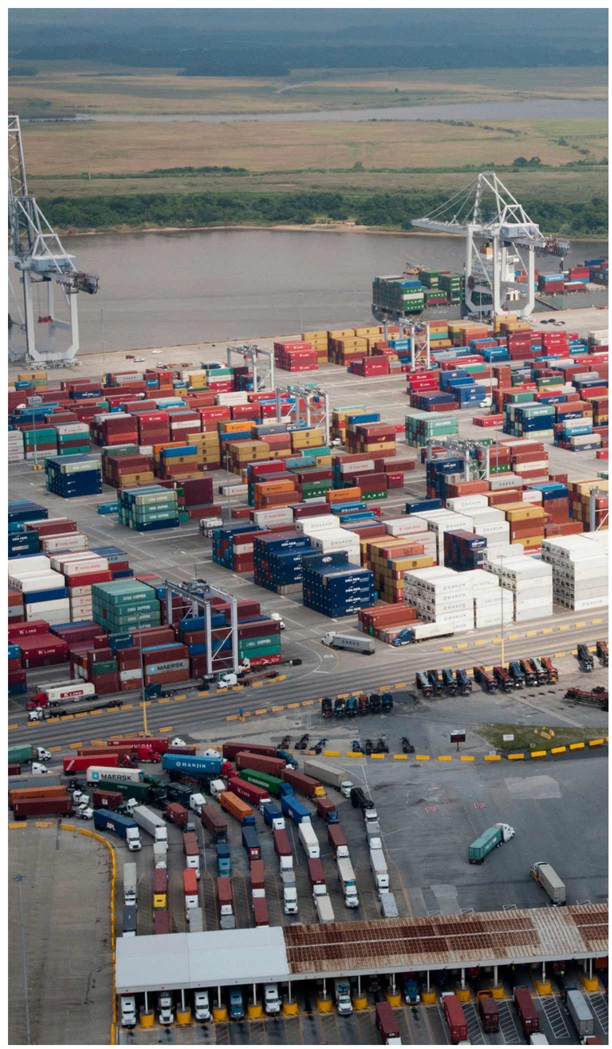
- The resulting increase in household disposable income is an important indicator of the net welfare gain. Enhanced infrastructure spending raises real disposable income, providing annual gains of $11 billion to $50 billion by 2030. Net of investment and after taxes, improvements to MTS infrastructure would imply a net gain in real annual income of $79 per household for the smallest program to $353 per household for the most ambitious proposal, measured in 2012 dollars.
- Sustained infrastructure spending creates a progressively more productive economy. Because of cumulative effects through time, by 2045 infrastructure investments could produce economy-wide returns of between $2 and $3 per every $1 spent, after adjusting for inflation.
- Enhanced economic growth from increased infrastructure investments ultimately would provide greater government revenue levels, which would help to recover the costs of higher public investment spending.

The Bottom Line

As multiple sectors of public infrastructure show increasing signs of aging and decay with no immediate plans for action, this seems an appropriate juncture to consider a highly focused infrastructure effort designed to improve safety, increase competitiveness, and improve economic throughput. Accelerated private and public sector efforts to develop MTS infrastructure, including a significant supply of new spending, allows the pursuit of two economic objectives at once:

1. New funding will help the United States catch up from a well-documented backlog of deferred infrastructure projects that have accumulated, including maintenance, repair, and new capacity.
2. Greater infrastructure investment will help to sustain economic growth and resiliency. By repairing and replacing old and obsolete infrastructure, we reduce the risk of failures that could cripple regional commodity flows or add substantial transportation costs that leave American industry at a competitive disadvantage. For relatively little additional expenditure on MTS infrastructure as a share of GDP, as is illustrated in this study, the U.S. economy not only can become larger but can become substantially more robust.

Widespread access to high-quality infrastructure is indispensable to the United States' economic development and standard of living. A more focused and outcomes-driven infrastructure effort is needed, and new ideas can, and should, accompany any increase in investment. Strong support exists within the business and manufacturing communities for building a more competitive, nationwide marine transportation system infrastructure network. This report reinforces the value of such action.



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ACRONYMS

AAPA	American Association of Port Authorities
ASCE	American Society of Civil Engineers
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
CBO	Congressional Budget Office
CEA	Council of Economic Advisers
CMTS	U.S. Committee on the Marine Transportation System
DOT	U.S. Department of Transportation
FAF	Freight Analysis Framework
FY	Fiscal Year
GDP	Gross Domestic Product
MTS	Marine Transportation System
NAICS	North American Industry Classification System
NAM	National Association of Manufacturers
NIPA	National Income and Product Accounts
O&M	Operations and Maintenance
OMB	Office of Management and Budget
PPP	Public-Private Partnerships
R&D	Research and Development
S&L	State and Local governments
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture

INTRODUCTION

The U.S. Marine Transportation System (MTS) plays a leading role in providing essential infrastructure services to businesses, consumers, and governments. The MTS consists of waterways, ports, intermodal landside connections, and supporting infrastructure that allow various modes of transportation to move people and goods to, from, and on the water. About 25,000 miles of navigable waterways[1], allow American farmers, manufacturers, and other producers to compete in world markets by keeping transportation costs low.

There are approximately 360[2] commercial marine ports and the U.S. Army Corps of Engineers (USACE) maintains the channels for 300 commercial harbors and more than 600 smaller ones[3], providing essential links to foreign markets through which billions of tons of goods flow each year. In 2017, major U.S. ports handled more than 873 million tons of domestic shipments and 1,512 million tons of international freight traffic (USACE, October 2018). Inland waterways carry more than 600 million tons of cargo annually (ASCE 2017). These systems do not operate in isolation, but instead they rely on connections to road, rail, pipeline, and other transportation infrastructure.

Despite the vital services these systems provide to the U.S. economy, many need long-overdue and substantial maintenance, repair, and modernization. The symptoms of decay are many, including lock shutdowns along U.S. waterways, which caused unexpected delays that totaled approximately 144,000 hours in 2016, an increase of nearly 90 percent since 2000 (Bureau of Transportation Statistics, 2017).

In the almost 46 years from 1956 through 2001, overall investment for public infrastructure rose, albeit at an average rate of about 1 percent lower than GDP growth. This suggests that capacity to move freight and passengers, to provide sufficient water utility services and other essential services, did not keep pace with the expanding needs of the overall economy. Over the past sixteen years, GDP has grown more slowly on average, but real infrastructure spending in fact contracted by 0.2 percent per year since 2001, lagging GDP growth by 2.2 percentage points.

Between 1956 and 2001, investment in water transportation infrastructure (waterways, ports, vessels, and navigational systems) also increased, with growth exceeding 4 percent annually from 1985 to 2001. Spending on water resources infrastructure (dams, levees, reservoirs, and other assets) also surged in these years. However, real spending for both water transportation and water resources infrastructure declined since 2001, with water transportation falling 1.4 percent per year and water resources contracting approximately 0.8 percent per year.

This report[4] presents a study of the economic

1 According to the USACE ("2017 Transportation Facts & Information," November 2018, www.usace.army.mil/Missions/Civil-Works/Navigation/), "Nearly 12,000 miles of inland and intracoastal shallow-draft waterways (9- to 14-foot draft) and 13,000 miles of greater than 14-foot deep channels, for a total of 25,000 miles are operated and maintained for commerce."

2 According to the "2017 Transportation Facts & Information" published by the USACE, larger ports alone numbered 186 in 2017, with each handling at least 250,000 tons of freight, including 109 large coastal ports, 42 that serve traffic on the Great Lakes, and 35 inland ports. According to the U.S. Maritime Administration, in 2009 there were "approximately 360 commercial sea and river ports" ("America's Ports and Intermodal Transportation System," January 2009, www.glmri.org/downloads/Ports&IntermodalTransport.pdf).

3 U.S. Maritime Administration, "America's Ports and Intermodal Transportation System," January 2009, www.glmri.org/downloads/Ports&IntermodalTransport.pdf. According to the USACE, "926 coastal, Great Lakes and inland harbors are maintained by the Corps" (www.usace.army.mil/Missions/Civil-Works/Navigation)

4 This research was performed at Inforum at the University

impacts of additional spending related to the U.S. MTS infrastructure. The work was sponsored by the U.S. Committee on the Marine Transportation System (CMTS). The CMTS is a Federal Cabinet-level partnership of more than 25 Federal Government departments, agencies, and bureaus directed under statute to coordinate and recommend policies related to marine transportation. The CMTS is directed to:

- Assess the adequacy of the MTS;
- Promote the integration of the MTS with other modes of transportation and marine uses; and
- Coordinate, improve coordination and make recommendations regarding Federal policies that impact the MTS.

Three alternative scenarios are considered for increased funding for operations and maintenance (O&M) and for capital improvements above a business-as-usual baseline. This study builds on previous assessments of the economic drag of degrading infrastructure. By alleviating such drag, to varying degrees, and by engaging in a 10-year capital improvement phase and permanently higher O&M spending, the overall economy may realize faster initial growth and permanently higher levels of GDP and income. This study employs an Inforum macroeconomic-industry, LIFT model to quantify those effects, building on past infrastructure studies that used the same model.

The first section presents a brief review of the literature and summarizes a series of projects that support this study. The following sections describe, in additional detail, the data, methods, and modeling techniques employed. The scenarios considered are described, finally followed by a summary of modeling results. Additional details, including a glossary of economic terminology and a description of the LIFT model employed, are included in the appendices.

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of Maryland with the support of the U.S. Committee on the Marine Transportation System at the U.S. Department of Transportation. The author is Ronald Horst. Questions may be directed to RHorst@umd.edu. More information about Inforum may be found in Appendix A and at www.Inforum.umd.edu.

LITERATURE REVIEW

Modern analysis of the economic effects of the MTS is limited. Still more limited is analysis of the economic role played by ports, canals, and other infrastructure systems that support waterborne commerce. Here we review recent key examples from the economic literature, paying particular attention to the antecedents of the current study.

The U.S. Congressional Budget Office (CBO, June 2016) reviewed the economic effects of Federal investment spending, which provides useful foundations for analyzing government investment spending in general. CBO defines three broad classes of non-defense Federal investment spending:

1. physical capital (mostly transportation) that directly contributes to the economy,
2. education and training that facilitates workforce development, and
3. research and development spending.

Each contributes to improving private-sector productivity. Federal investment might be carried out directly, such as USACE construction of a dam, or it might be carried out by supporting state and local activities, or through support of the private sector.

While much of Federal investment is helpful to the private sector, and transportation and other public infrastructure are vital, the effects of investment are varied. Though investment often enhances productivity and capacity in the longer run, the immediate effect of spending might be the reduction of other activity that would have taken place. This can happen, for example, when increased public borrowing to facilitate construction causes interest rates to rise, thereby discouraging borrowing to fund residential construction and automobile purchases. If investment costs are paid through higher tax rates, then these too can discourage other economic activity. On the other hand, increased government investment also leads to higher output, both in the short run through higher spending and in the long run by enhancing productivity and production capacity. These countervailing effects have important and potentially significant macroeconomic consequences that ripple throughout the economy. Particularly in the short run, some sectors might be hurt by higher spending even if overall employment and output rise. As the economy adjusts in the long run, the benefits of the higher capital stock are distributed more widely.

The President's Council of Economic Advisers (CEA, February 2018 and March 2018) calls repeatedly for large infrastructure projects, suggesting that \$1.5 trillion to \$2.0 trillion is needed to improve transportation and other infrastructure. The CEA estimated the economic effects resulting from such efforts could yield an increase in annual average GDP growth by 0.1 to 0.2 percentage points over ten years. Actual effects toward the higher end of the range could be realized if:

1. the regulatory process is streamlined,
2. economically efficient means of funding infrastructure investment are adopted,
3. innovative financing methods like public-private partnerships (PPPs) are employed, and
4. the highest-value potential projects are identified and scarce funding dollars are directed to them.

Like the CBO, the CEA acknowledges that public spending can displace other activity. A large program, as is recommended by the Administration, could employ an average of 290 to 414 thousand construction workers, but some of these workers would be pulled from other construction, manufacturing, and other sectors so that the net total employment increase would be lower. On the other hand, many longer-run effects clearly are positive, with the increased stock of public infrastructure providing a greater flow of capital services. These enhance GDP growth by complementing other factors of production such as labor, private capital, and land, which makes private industries more productive and encourages greater private investment spending. A second effect on GDP comes through the public sector, as capital deepening – increasing the ratio of infrastructure capital per worker – makes public workers more productive; though this second effect is smaller, both are important.

The U.S. Department of Agriculture (USDA, 2019) studied the effects of inland waterways on American production of agriculture. U.S. industry relies heavily on the Mississippi River, Great Lakes, and other navigable waterways. Inadequate infrastructure reduces transportation capacity, thereby raising effective prices for waterborne transportation and leading to greater reliance on trucking and railroad. These higher transportation costs lead to higher prices for U.S. exports, reducing the competitiveness of American agricultural goods. This reduces income for American farmers and hurts the U.S. economy. For example, USDA compared costs for exporting soybeans to China. In 2018, export costs from Davenport, IA were slightly lower than export costs for North Mato Grosso, Brazil, despite lower costs for growing soybeans in Brazil and greater marine shipping costs due to greater distances for U.S. exports. The key advantage is that U.S. producers have access to low-cost inland waterway transportation, while Brazilian exporters rely far more heavily on trucks to move soybeans from farms to marine ports. Although farmers in Iowa maintain a slight advantage now, continued deterioration of U.S. infrastructure soon may push American export prices above those of its Brazilian competitors.

The American Society of Civil Engineers (ASCE) regularly assesses the condition of U.S. infrastructure and assigns grades, published most recently as the 2017 Infrastructure Report Card (ASCE 2017). ASCE assigned inland waterways a grade of D, while ports earned a grade of C+. Barges move heavy, bulky freight far more efficiently than trucks or even rail, reducing costs and emissions. Inland and intercoastal waterways connect inland and marine ports, thus providing access to foreign markets for communities sometimes many hundreds of miles from the sea. ASCE noted that most locks and dams within the system of waterways are beyond their 50-year design life. This contributes to delays for 49% of vessels traveling within the system, and the average length of delays is increasing.

The Nation's commercial inland, Great Lakes, and marine ports handle the bulk of U.S. overseas trade in goods. While these ports earned a better score than did inland waterways, freight flows through these ports nonetheless are hampered by inadequate land-side road and rail networks. As ships become larger, shallow shipping channels and low bridges also restrict water-side freight movements to and from marine ports. The expanded Panama Canal allows larger ships from Asia to reach East Coast ports, but few ports have the capacity to receive them. Investment needs are not due solely to the development of larger ships, but regular efforts also are needed to dredge sediment deposits that otherwise restrict traffic through harbor channels and canals.

In recent years, Inforum conducted a series of studies concerning the economics of public infrastructure, first identifying the economic consequences of poor infrastructure and then considering the implications of various plans to develop better infrastructure.

From 2011 through 2013, Inforum worked with research partners to identify the economic consequences of degrading public infrastructure[1]. The series included analyses of surface transportation; water supply and wastewater; electric power production; airports, marine ports, and inland waterways; and a final summary study that considered degradation of all of these systems. Study partners used micro-level or other specialized and specific data on transportation and other systems to calculate the direct economic effects of worsening infrastructure quality on

1 The American Society of Civil Engineers sponsored the effort and published the "Failure to Act" series of reports between 2011 and 2013, with an update published in 2016. www.infrastructurereportcard.org/the-impact/failure-to-act-report.

its users. For degrading surface transportation systems, such effects included lower labor productivity and increased fuel use for the trucking industry, and it included additional spending on tires and higher prices paid for public transit by households. Higher trucking costs mean higher prices for delivered goods, and higher transportation costs for households mean reduced savings or less spending on other goods and services. Consequences extend beyond those easily evaluated in economic terms; for example, wasted time due to traffic congestion means fewer hours available for work, other responsibilities, and leisure.

The analysis of water transportation infrastructure assessed direct economic effects of degrading marine port and inland waterway infrastructure (ASCE 2012). Direct effects were identified and derived using USACE historical data and U.S. Department of Transportation (DOT) Freight Analysis Framework (FAF) projections of commodity shipments by water. From these data, research partners derived direct effects, in the form of excess costs per unit shipped, for domestic production, imports, and exports.

Excessive costs reduce international trade by making imported goods more expensive, thus making foreign goods less attractive to domestic buyers, and by making goods exported from the U.S. relatively more expensive for foreign buyers, thus reducing the competitiveness of American firms in overseas markets. Higher imported prices drive up costs for firms and households that depend on those commodities. Some savings through substitution are possible, for example the substitution of lower-priced imported goods or domestically-produced goods, but higher prices due to inefficient transportation systems make U.S. production more expensive and reduce purchasing power for American consumers. These additional costs directly drive up prices for American-made goods. Higher prices make American goods less competitive, both in American and in foreign markets.

The 2011-2013 ASCE *Failure to Act* series focused entirely on the economic costs of degrading infrastructure. In 2014, Inforum and the National Association of Manufacturers (NAM, 2014) extended the 2013 *Failure to Act* comprehensive cost analysis (including transportation, water supply, and wastewater systems but excluding electric power production) by considering effects of higher levels of government investment spending. This work illustrated not only the economic drag caused by inefficient and costly systems, which only increase over time unless alleviated by greater investment spending, but it also showed the economic benefits in the short to medium-run of higher levels of construction spending.

An economic analysis for Business Roundtable (2019) extended the NAM (2014) study in several important ways. The first was to identify in the National Income and Products Accounts (NIPA), the key macroeconomic data set upon which Inforum's LIFT model is built, revenue streams associated with infrastructure that fund federal, state, and local governments. These include, for example, fees on personal and commercial drivers' licenses, fuel taxes, and utility and airport fees. Inforum used these revenue streams in its modeling work to consider the implications of raising funds to pay for higher government investment spending, in contrast to the alternative of funding development with long-term debt.

A second extension was to model the participation of private enterprises in the provision of public infrastructure through PPPs. Private enterprise long has been engaged in these activities, where the traditional approach is that private firms bid for particular projects and tasks but for government entities to remain fully responsible for the design, construction, operations, and maintenance of infrastructure. Under conventional procurement practices, responsibility for different project phases is split among various independent firms, and no one firm has an incentive to minimize total costs over the project's life cycle (U.S. Treasury, May 2016). Fragmentation also increases the chances of cost overruns and scheduling delays, particularly if design and construction functions are not properly coordinated. If the potential exists for "bundling" different project phases under a contract with a single private entity, then a PPP may be preferable to conventional procurement methods (U.S. Treasury, May 2016). In these studies, Inforum thus modeled a greater role for the private sector, not only in the construction phase, but also in the operations and maintenance of public infrastructure.

ECONOMIC CONCEPTS AND TERMINOLOGY

Two broad categories of infrastructure spending are[1]:

1. investment, or capital spending, and
2. operations and maintenance (O&M) spending.

Investment includes spending on structures, equipment, and intellectual property such as software; in some cases, additional types of spending are included in the category, such as real estate purchases. Because definitions vary for capital spending, the following text clarifies the use of such terms by agencies that provide such data.

O&M includes the performance of routine, preventive actions intended to prevent failure or decline with the goal of increasing efficiency, reliability, and safety.

The U.S. national accounts provide a comprehensive and consistent framework for defining, measuring, and analyzing the American economy. For example, the U.S. Census Bureau collects data on private and public construction spending, and the Bureau of Economic Analysis (BEA) employs these data in the development of the national accounts (these accounts include NIPA, together with the integrated Fixed Assets accounts, industry accounts, and other data sets).

The greatest part of investment in public infrastructure is spending on construction. Together with spending on equipment and intellectual property, investment in structures contributes to GDP. Extensive detail on construction spending is provided in the national accounts and is useful for infrastructure analysis. While other important types of spending also are represented in the accounts, teasing out other infrastructure spending details often requires use of additional data sources. Other important forms of spending are not considered to be investment for purposes of national accounting, but these expenditures reflect the costs of infrastructure projects and contribute to public and private debt. A prime example is the purchase of real estate; this is included in broader measures of infrastructure investment spending, but it is not included among the investment figures reported in the national accounts.

1 A glossary of economic terms is included at the end of the text.

National accounts and other economic datasets typically split spending for MTS infrastructure between two categories: Water Transportation and Conservation and Development.

Water Transportation assets include such things as docks, piers, wharves, marinas, dry docks, boatels, and maritime freight terminals. Water Transportation assets sometimes are included in a broader Transportation infrastructure category that includes air, rail, transit, and other facilities.

Conservation and Development extends well beyond transportation assets to include categories such as irrigation, mine reclamation, fish hatcheries, wetlands, erosion control, and flood-control levees. This category also includes non-power generating dams, locks and lock gates, breakwaters, jetties, sea walls, and non-irrigation related dredging. Each of these latter items, at least in part, contribute to transportation systems, but conservation and development also includes activities that are not related to transportation. The non-irrigation dredging component, which is vital to facilitate transportation, is considered to be capital spending, and thus these important activities appear below in the investment figures.

The CBO definition of investment is somewhat broader than the BEA and Census Bureau definitions as the CBO measures include real estate purchases. CBO capital spending categories include "amounts for the purchase, construction, manufacture, rehabilitation, or major improvement of physical assets regardless of whether the assets are owned or operated by the Federal Government, States, municipalities, or private individuals. Physical assets are land, structures, equipment, and intellectual property (for example, software) that have an estimated useful life of two years or more, and commodity inventories (CBO, November 2010)."

O&M expenditures shown in the CBO data are those for "noninvestment activities." According to CBO practices, "operation and maintenance spending also includes investment in intangible assets (for instance, for research and development) as well as expenditures for administrative activities and public outreach (such as safety and educational programs)." This treatment of spending for intangible assets, including software and research and development (R&D), is not entirely consistent with the practices of the BEA. BEA defines such spending on intangible assets, including both software and R&D, to be investment, while CBO classifies expenditure for software to be investment and R&D expenditure to be O&M. The intellectual property spending share for public infrastructure likely is small, and so the discrepancy is of little consequence for the present study.

CBO focuses on the types of infrastructure that "share the economic characteristics of being relatively capital intensive and producing services under public management that facilitate private economic activity. They are typically the types examined by studies that attempt to calculate the payoff, in terms of benefits to the U.S. economy, of the public sector's funding of infrastructure." Of the seven categories considered by CBO, this report focuses on two. CBO defines two categories concerning the MTS that are similar to those defined by the Census Bureau and BEA, namely Water Transportation and Water Resources.

Water Transportation includes items such as waterways, ports, vessels, and navigational systems. Water Resources, like the BEA Conservation and Development category, is broader; it includes containment systems, such as dams, levees, reservoirs, and watersheds, and it includes sources of fresh water such as lakes and rivers.

Water Resources also includes spending on dredging; CBO notes "The Army Corps of Engineers' projects to support water navigation are included in the water resources category of infrastructure spending along with all other infrastructure spending by that agency."

In this report, terms such as "Water Transportation, "Conservation and Development," and "Water Resources" reflect concepts and data standards widely used by economists. In particular, economic data published by BEA, Census Bureau, CBO, and other agencies conform to these standards. These are related to the MTS concepts employed by CMTS and other agencies, but important differences exist, as described above. In the text that follows, presentation and use of economic data and concepts will conform to the standards of the economics literature, while commentary on the broader subject will employ the MTS nomenclature.

HISTORIC ECONOMIC DATA

The following provides a quantitative review of historic spending on transportation infrastructure in the U.S., together with measures of industry revenue and other statistics. The review includes historical data provided by the CBO (2018), where the CBO assembled funding and spending data from information supplied by the Office of Management and Budget (OMB) and the Census Bureau. In addition, information was obtained from the BEA Fixed Assets accounts and NIPA, the Census Bureau, and the Bureau of Labor Statistics (BLS).

The CBO published a series of reports on infrastructure spending in the U.S.; this document employs data from the 2018 edition (CBO, October 2018). CBO obtains Federal accounting data from OMB, and CBO identifies some of these line items as Federal infrastructure funding. Together, these line items present an estimate of total Federal infrastructure funding for capital spending and for O&M activities[1]. CBO separates these items according to:

- type of infrastructure (roads, mass transit, rail, water transportation, water resources, and water supply and wastewater),
- whether it is capital or O&M funding, and
- whether the Federal government spends the money directly or whether it provides grants to state and local (S&L) governments.

1 For a few Federal categories, CBO relies on tables in other OMB reports rather than on the OMB line item data.

Figure 1. Average Age of Structures (1927-2018)

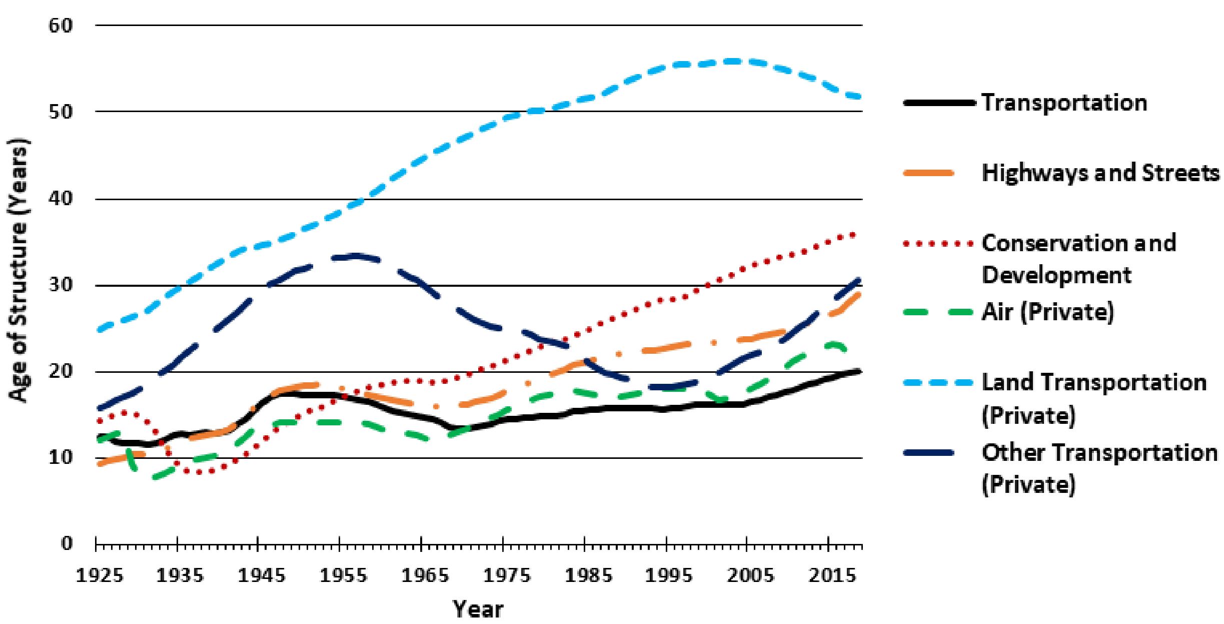


Figure 1 displays the average age of public and private components of transportation infrastructure, as calculated and published by the BEA. These reflect the average age of structures only, as data on associated equipment and intellectual property is not provided. Public categories include Transportation, such as mass transit and waterways; Highways and Streets; and Conservation and Development, which includes categories such as levees, dams, and locks. Private categories include the two components of Transportation, Air and Land, where Land primarily is rail assets, and it includes an "Other Structures" category that includes conservation and development. *Source: Bureau of Economic Analysis*

CBO obtains S&L spending data from the Census Bureau for the same or similar types of infrastructure derived for Federal spending, and these also distinguish capital and O&M spending. The Census Bureau data includes all infrastructure spending by S&L governments regardless of the source of funds. Together, the OMB and Census data imply both self-funded and federally supported spending by S&L governments.

In addition to data compiled by CBO, BEA presents a variety of investment data, other spending data, revenue data, and additional information concerning public transportation infrastructure. From the investment data that BEA compiles in their Fixed Assets accounts, they calculate the average ages of various types of capital stock. In particular, they offer extensive detail on various types of public and private structures.

By far, the oldest set of structures is private rail; these assets had been aging for many decades, but higher investment spending more recently has begun to reduce the average age (Figure 1). Just behind private rail is public Conservation and Development assets; these are aging rapidly, as investment spending for dredging, dams, and other components has failed to keep up. The public Transportation category includes air, rail, transit, and other components along with inland waterways and marine ports. The extent to which these numbers represent the average age of water transportation structures in particular is not clear. Like private rail assets, many public systems such as dams and locks are quite old. However, the decreasing average ages for the broader Transportation category may be a result of recent spending on certain transportation modes such as air and mass transit.

The average age of public Conservation and Development assets might be a better proxy for public water transportation assets in general, and this is rising at a worrisome rate. With advancing age comes deterioration in quality and capacity, particularly when age extends beyond design horizons and when maintenance has been inadequate, leading to delays that inhibit private activity. Indeed, the overall average age of the 239 lock chambers is over 60 years, and almost 80% of locks in the U.S. have well surpassed their intended service lives[2].

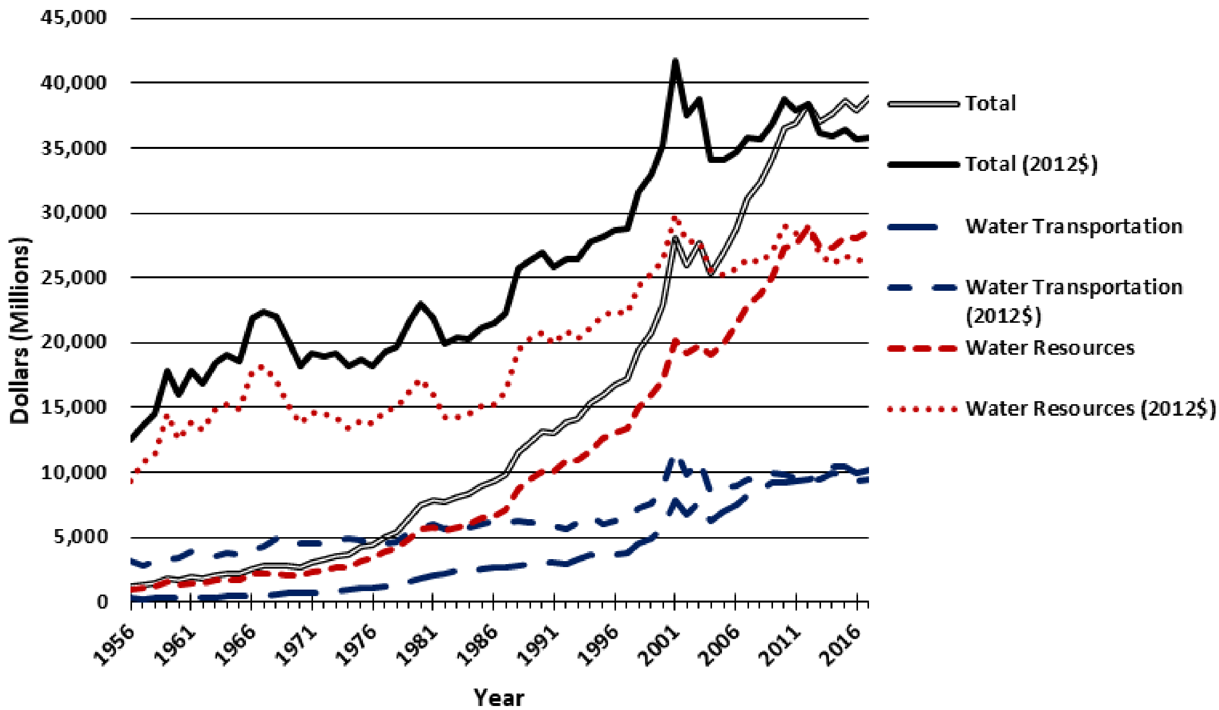
Spending on water transportation and water resources is shown in Figure 2, together with the combined amount. Both nominal spending and real (inflation-adjusted, in 2012 dollars) expenditure are shown. Spending on water resources is far greater than for water transportation, though water resources includes flood control and other expenditure not related to transportation. Public spending on water resources infrastructure reached $28.7 billion in 2017, while spending on water transportation rose to $10.2 billion. Since 2010, nominal spending has risen slowly, and real spending has fallen. This implies that prices have risen so that while the amount of dollars spent is greater today, the amount of investment and O&M activity purchased with these dollars is less than was seen historically. Indeed, despite a substantial surge in 2001-2003 and a smaller increase likely funded by stimulus programs in the last recession, real spending has been flat since 2000; real spending in 2000 and 2017 was just over $35 billion.

To facilitate growth of the American economy, the flow of services from public infrastructure must increase. This typically requires that the stock of infrastructure should expand to keep pace with economic growth. Figure 3 shows that spending for both water transportation and water resources is falling in proportion to GDP. Combined spending for these assets reached a high of 0.356 percent of GDP in 1959, but by 2017 spending slipped to 0.199 percent of GDP. Occasional reversals in the trend have not lasted long, and the slide since 2010 has been steep.

Nominal capital spending stood at $11.7 billion in 2017, while O&M spending climbed to $27.2 billion (Figure 4). Public investment spending surged in the late 1990s and peaked in 2001 at $13.1 billion at nearly $4.5 billion spent on water transportation and $8.6 billion spent on water resources. Despite this notable surge in capital spending, real investment

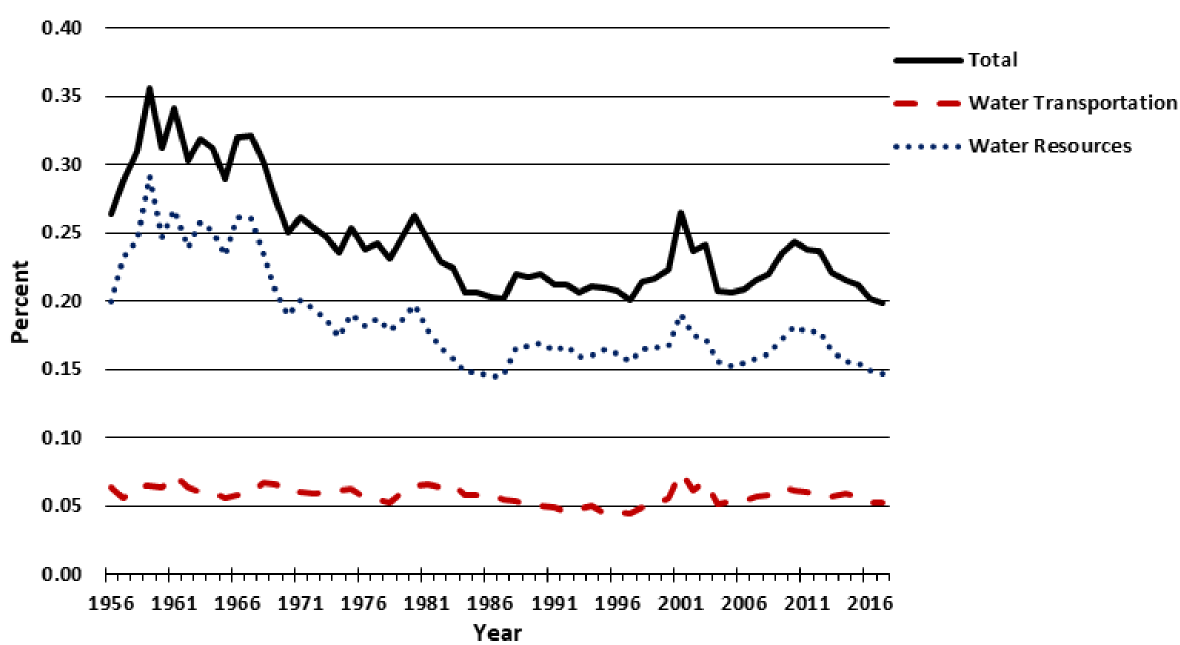
2 Waterways Council Inc., "In the News," 2019. Retrieved from waterwayscouncil.org/media/in-the-news#:~:targetText=The%20average%20age%20of%20these,%2Dyear%2Dold%20design%20life.

**Figure 2. Public Infrastructure Spending (1956-2017)
Millions of Nominal and 2012$ Dollars**



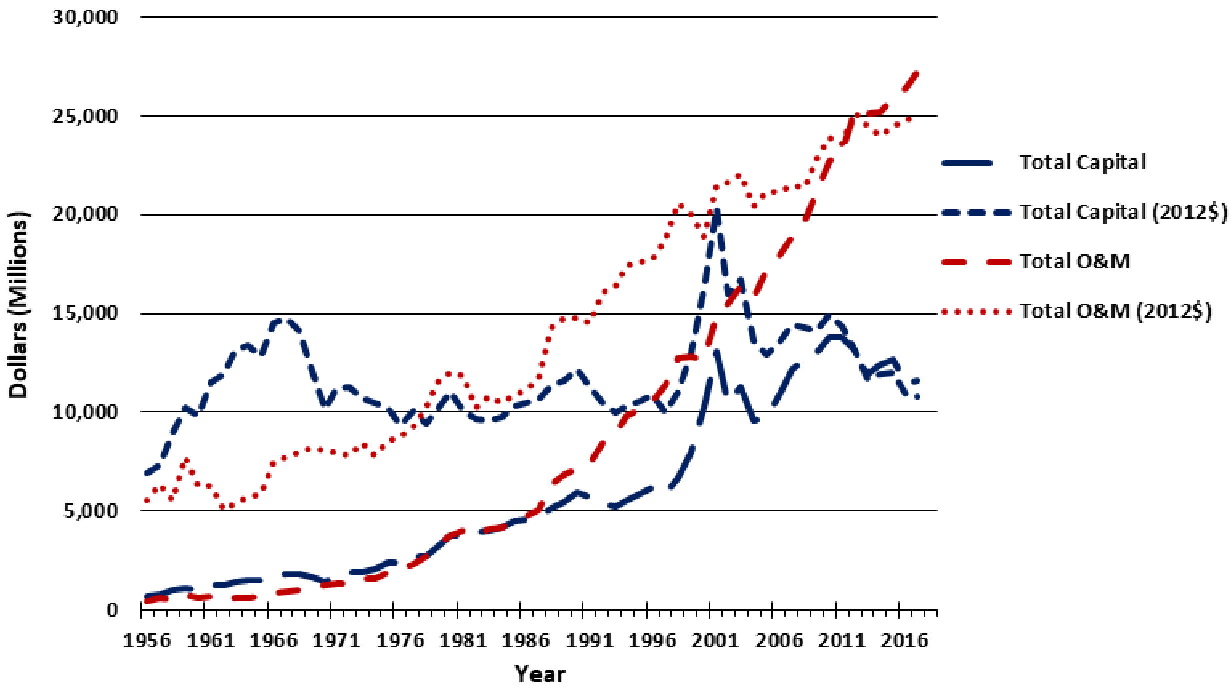
Source: Congressional Budget Office (2018)

**Figure 3. Public Infrastructure Spending (1956-2017)
Percent of Nominal GDP**



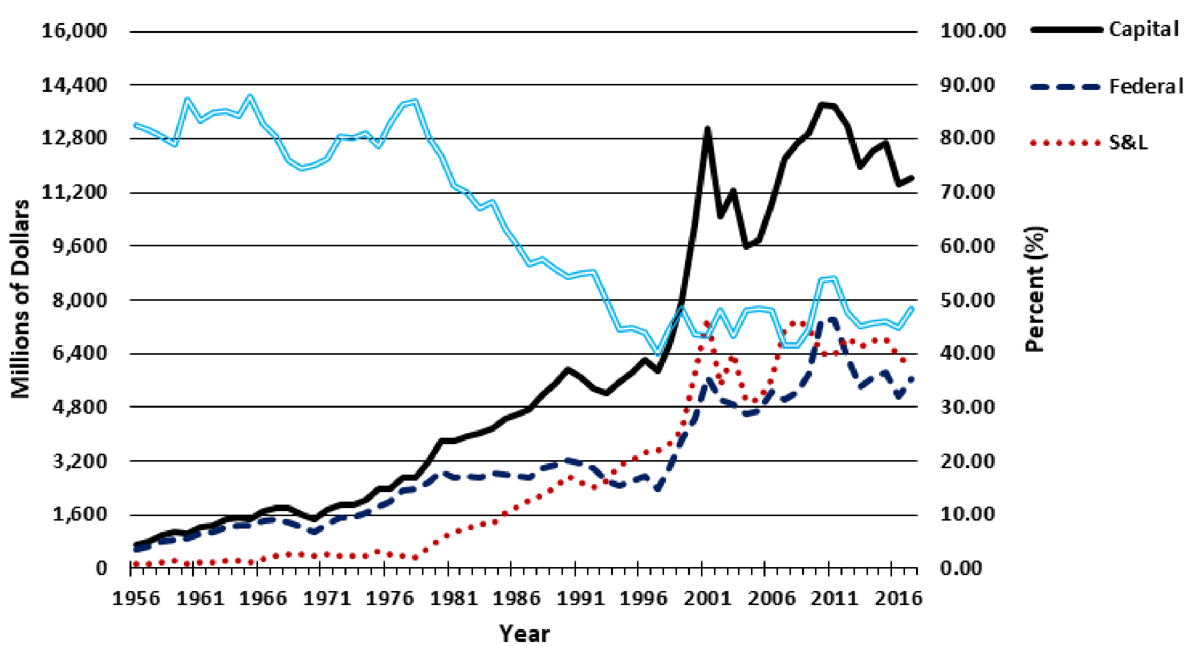
Source: Congressional Budget Office (2018), Bureau of Economic Analysis (October 2019), and author's calculations.

Figure 4. Components of Public Infrastructure Spending (1956-2017)
Millions of Nominal and 2012$ Dollars



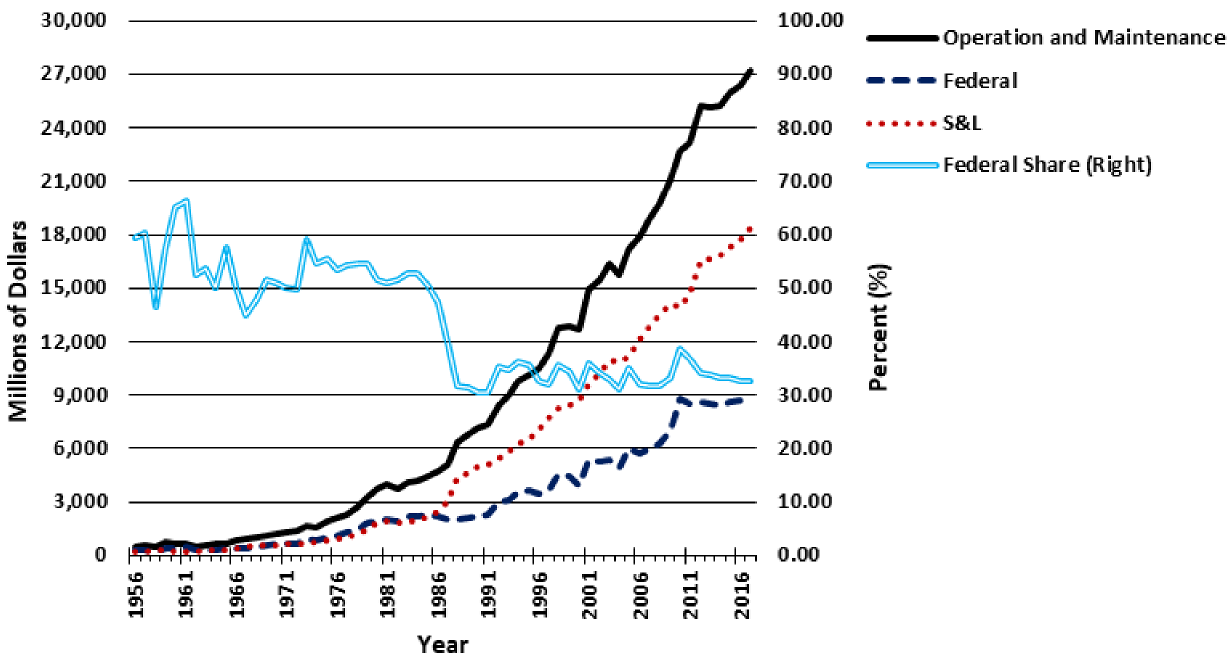
The primary components of total expenditure, investment and O&M spending, are shown. The figure shows combined figures for water transportation and water resources. *Source: Congressional Budget Office (2018).*

Figure 5. Public Infrastructure Investment Funding (1956-2017)



These data indicate combined spending on water transportation and water resources infrastructure. *Source: Congressional Budget Office (2018) and author's calculations.*

Figure 6. Public Infrastructure O&M Funding (1956-2017)



These data indicate combined spending on water transportation and water resources infrastructure. *Source: Congressional Budget Office (2018) and author's calculations.*

expenditure largely has been flat since the early 1960s. O&M spending displays no similar surges, but since 1983 O&M expenditure has exceeded capital spending in nominal terms, and real capital spending fell behind beginning in 1978.

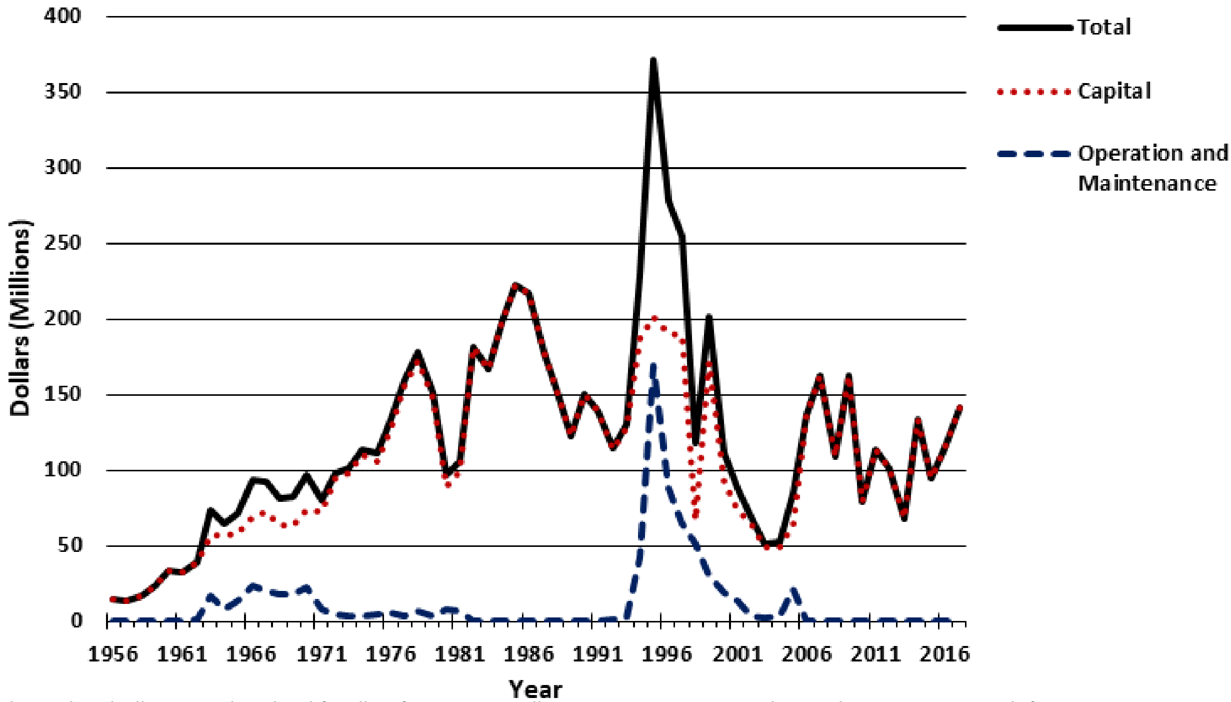
Both the Federal government and S&L governments fund capital spending for water infrastructure. Figure 5 shows that the share of Federal investment funds has fallen from nearly 90% in the 1970s to less than 50% in 2017. Of the $11.7 billion in public expenditure in 2017, the Federal government provided $5.6 billion and S&L governments provided $6.0 billion. Funding by both surged in the years around 2000, but it was the Federal government that provided stimulus spending around 2010.

Figure 6 illustrates that the share of Federal O&M funding fell from more than 60% in the early 1960s to just over 30% in 2017, with a notable drop in the share occurring in the mid-1980s when S&L funding surged. Total O&M funding rose to $27.2 billion in 2017, with the Federal government supplying $8.9 billion and S&L governments providing $18.3 billion.

In contrast to many other types of public infrastructure, with roads and highways a prominent example, the Federal government provides relatively little financial support for S&L investment and O&M spending on water transportation and water resources. Most Federal funding for these types of infrastructure is spent directly on USACE and other Federal projects such as inland waterways, and most S&L projects such as docks are funded by S&L revenue[3]. The Federal government does provide some financial support for these projects, as is summarized in Figure 7. Most support takes the form of capital transfers that boost S&L investment spending. In certain eras, with the 1990s the most significant case, the Federal government helped with O&M activities by S&L entities, but CBO reports little or no assistance in recent years. Of the $141 million in Federal aid provided in 2017, all of it went to capital projects.

3 Recall that available economic data do not provide precise measurement of activity according to water transportation or MTS infrastructure concepts. Instead, relevant activities such as dredging are combined with activities that serve other purposes, such as irrigation and flood control; these totals are reported as Water Resources or as Conservation and Development categories. When combined with Water Transportation infrastructure statistics, as shown here, the estimates of public spending and funding thus provide an upper bound for transportation-related activity. CBO (2018 and earlier reports) provides additional details.

Figure 7. Federal Support for S&L Spending (1956-2017)

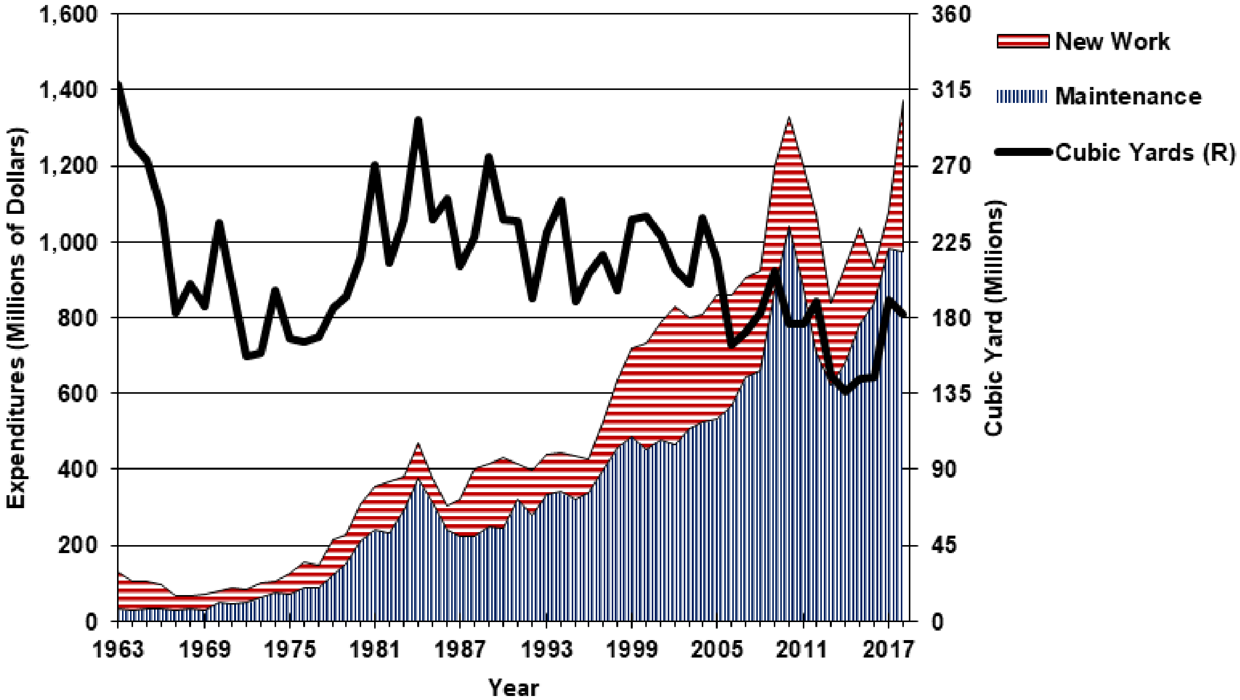


These data indicate total Federal funding for S&L spending on water transportation and water resources infrastructure.
Source: Congressional Budget Office (2018).

The Federal government plays a critical role in the development and maintenance of MTS infrastructure. To maintain shipping channels and waterways, the USACE either directly or through contractors dredged 230.8 million cubic yards of material from shipping channels in 2017, at a cost of $1.4 billion. Spending to maintain existing channels accounted for 94.9 percent of the material dredged, another 2.5 percent was due to recovery from Hurricane Sandy, and 2.6 percent was new construction and channel deepening (USACE, October 2018). These dredging costs are partially supported by annual appropriations from the Harbor Maintenance Trust Fund, which was valued at $9.3 billion in 2018 (Department of the Treasury, 2019). In addition, the Inland Waterways Trust Fund supports the renovation and construction of waterways. At the start of 2018, $63.4 million was left in the fund for new construction projects, compared to an estimated $33.3 million available in 2019 (Inland Waterways Users Board, 2018). Figure 8 shows the amount spent by the USACE on dredging activities over the past 56 years. Following a surge of spending in 2009 and 2010, spending fell sharply, though it increased again in 2015 through 2018. Despite improvements in efficiency, cubic yards removed remains on a decades-long downward trend.

Because so much commodity trade is moved by water, including a large percentage of U.S. exports of manufactured goods and agricultural and energy products, it is essential to maintain MTS infrastructure along our coasts and inland waterways. Failure to do so induces excess costs for shipping companies and their customers. In 2016, the average delay for operating a lock was 2.4 hours, and lock shutdowns along U.S. waterways as a result of maintenance and unexpected delays totaled approximately 144,000 hours in 2016, an increase of nearly 90 percent since 2000 (Bureau of Transportation Statistics, 2017). Unscheduled delays and congestion caused by challenges related to infrastructure at ports and waterways add considerable costs, leaving domestic products less competitive in international markets and driving up prices for U.S. consumers. Well-functioning MTS infrastructure also helps the U.S. to save money. It costs about $13.72 less per ton to transport goods using water transportation versus other modes,

Figure 8. U.S. Army Corps of Engineers Dredging Activity (1953-2018)



Source: U.S. Army Corps of Engineers (2018).

saving about $7.6 billion annually. Other benefits of water transit include less air pollution, accidents, and road congestion (USACE, January 2018).

Spending to develop and maintain the capital stock of MTS infrastructure, together with spending to operate the capital stock, allows a flow of capital services that facilitates private and public activities. For example, the ports and waterways directly serve 41 states, with a total of 25,000 miles of navigable waterways for commerce. U.S. waterways transport about 1/6 of the freight that travels between cities. Our nation's agricultural sector depends heavily on water transportation; over 60 percent of exports from this industry travel over inland waterways to reach international buyers, while 80 million tons of grain travel by boat every year (USACE, January 2018).

According to USACE (October 2018), 873.1 million tons of commodities were shipped among U.S. lakes, inland waterways, and coastal waterways in 2017, though total tons shipped fell 0.4 percent in 2017. The following illustrates the volume of goods moving through the MTS:

- Petroleum products and crude petroleum are the leading products, by weight, at 79.4 million and 44.1 million short tons, respectively (USACE, January 2018).
- Foreign shipments totaled 1,512 million short tons.
- Imported shipments rose to 766 million tons, up 1.4 percent from 2016.
- Though crude petroleum imports fell 3.1 percent, it still leads commodity imports at 271.4 million tons.
- Exports by weight increased an impressive 13.1 percent in 2017 to 746.1 million tons.
- Petroleum products gained 12.1 percent to reach 227 million tons.
- By weight, 14.2 percent of waterborne commerce was shipped in containers, including 2.5 percent of domestic shipments and 21 percent of foreign trade shipments.
- More than 2 million containers were shipped domestically, and more than 22 million were shipped internationally in 2012.

These shipments passed through 8,239 cargo-handling docks, with 73 serving only foreign

Figure 9. Gross Output by Industry (1997-2017)

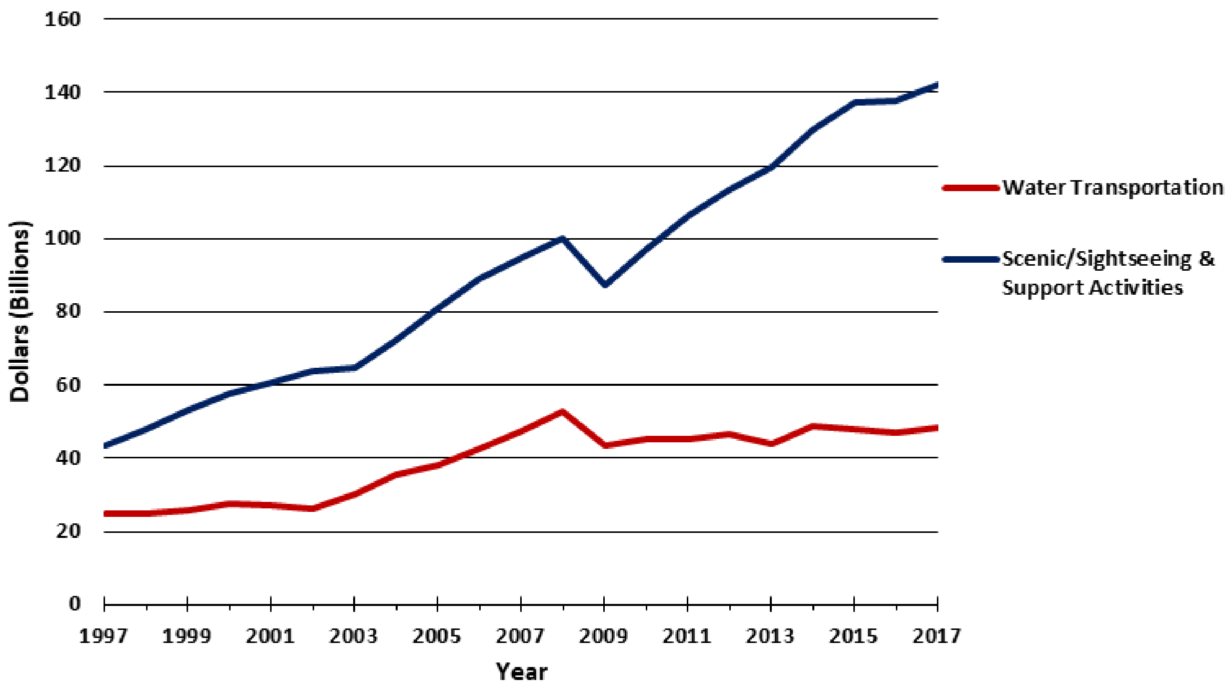


Figure 9 shows the amount produced by the water transportation industry between 1997 and 2017. *Source: Bureau of Economic Analysis*

shipments, 6,032 serving only domestic traffic, and the rest serving both. The shipments also depend on highways, railways, and pipelines to bring outbound freight to the port and to move inbound freight from the port to its destination.

The BEA provides measures of private and public-sector production activities in the form of Gross Output by Industry. These data are part of the national accounts and imply the use and the operation of infrastructure. As seen in Figure 9, water transportation business peaked in 2008 at $52.8 billion, but production in 2017 was just behind at $48.3 billion. These data for the provision of water transportation services imply the use of water transportation infrastructure. The actual operation of water transportation infrastructure is included in the other category shown, Scenic, Sightseeing, and Transportation Support Activities. This is a broad category that includes components of recreational transportation and transportation support services that are not related to water transportation. The transportation support component includes activities such as motor vehicle towing services, bus and rail stations, and airports. While the $142.3 billion produced by this sector in 2017 includes components relevant to this study, we look beyond the national accounts to find such details.

Table 1 shows industry revenue figures for transportation of people and freight as published by the U.S. Census Bureau in their Service Annual Survey. Detail is shown for various components of water transportation services and water transportation support services. Transportation services as defined include passenger and freight services for deep sea, coastal and Great Lakes, and inland routes. In 2017, similar amounts were earned for freight shipments in each category, with slightly more for inland waterway transportation. About 96% of passenger spending in 2017 was for Deep Sea Transportation. These activities are facilitated by support services that include the operation of infrastructure. These categories include port and harbor operations, marine cargo handling, navigational services, and other support activities. Water transportation revenue of $42.2 billion reported for 2017 is similar to the $48.3 billion published in the gross output accounts. Data are incomplete for transportation support in 2017, but

Table 1. Transportation Services and Transportation Support Services Revenue
Millions of Dollars

NAICS Description	2013	2014	2015	2016	2017
Water Transportation	**42,807**	**45,132**	**44,003**	**42,806**	**42,187**
Deep Sea Freight Transportation	9,530	9,215	8,443	7,656	6,167
Deep Sea Passenger Transportation	16,875	17,985	18,593	19,692	21,370
Coastal and Great Lakes Freight Transportation	7,657	7,909	7,509	6,872	6,505
Coastal and Great Lakes Passenger Transportation	387	432	492	524	589
Inland Water Freight Transportation	8,064	9,281	8,652	7,742	7,186
Inland Water Passenger Transportation	294	310	314	320	370
Water Transportation Support	**17,143**	**18,483**	**19,528**	**18,951**	**NA**
Port and Harbor Operations	2,565	2,625	2,809	2,915	NA
Marine Cargo Handling	9,046	10,034	10,782	10,080	10,116
Navigational Services to Shipping	3,349	3,426	3,503	3,499	3,616
Other Support Activities for Water Transportation	2,183	2,398	2,434	2,457	2,519

Source: U.S. Census Bureau, Service Annual Survey.

Table 2. Estimated Sources of Transportation Services Revenue for Employer Firms
Millions of Dollars

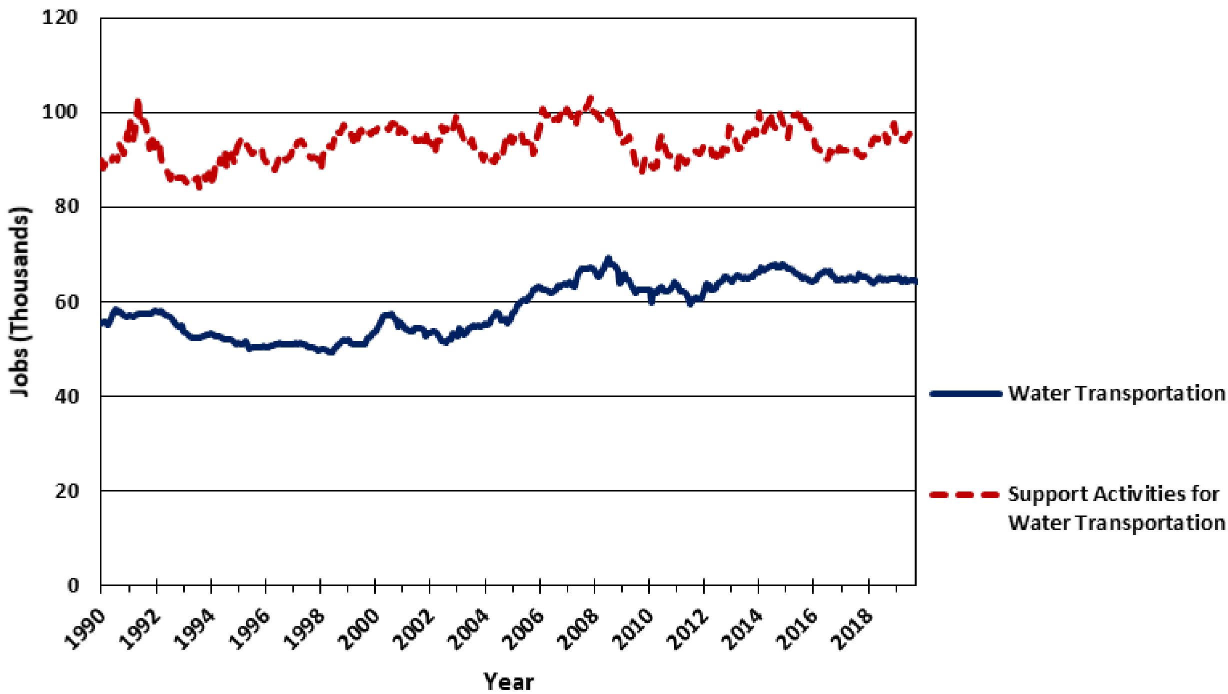
Item	2013	2014	2015	2016	2017
Total operating revenue	**42,807**	**45,132**	**44,003**	**42,806**	**42,187**
Transportation of freight and cargo by water	21,359	22,405	20,843	18,869	16,362
Towing services by water	1,171	1,263	1,148	1,132	1,112
Harbor tugboat services	468	491	403	365	344
Coastal and Great Lakes fixed-route, passenger transportation by water	373	426	405	407	434
Cruises	16,900	18,033	17,649	18,667	NA
Participatory recreational services by water craft, except overnight cruises with cabin accommodation	S	S	1	1	1
Sightseeing by water	23	25	14	15	16
Other transportation of passengers by water	49	53	85	93	105
All other operating revenue	2,463	2,435	3,455	3,257	3,467

Source: U.S. Census Bureau, Service Annual Survey.

2015 and 2016 revenue figures were approximately $19 billion. The greatest portion of this was earned by marine cargo handlers, followed by navigational services, port and harbor operations, and other support activities. Other support activities include floating drydocks (i.e., routine repair and maintenance of ships), marine cargo checkers and surveyors, ship dismantling at floating drydocks, and ship scaling services not done at a shipyard. Not shown is revenue for the Freight Transportation Arrangement industry, though those activities support water transportation as well as other transportation sectors.

Revenue earned through the provision of particular services by the water transportation industry is shown in Table 2. Of the $42.2 billion in revenue gained in 2017, $16.4 billion was earned by transporting freight. Figures for cruises are not available for 2017, but these revenue figures usually

Figure 10. Water Transportation and Support Services Employment (1990-2019)



Source: Bureau of Labor Statistics, Current Employment Statistics.

follow just behind the freight figures; the cruise industry earned $18.7 billion in 2016. More than $1 billion went to towing services and just over $500 million went to various passenger services, while less than $500 million went to harbor tugboat services.

Another measure of industry activity is employment. As is shown in Figure 10, the water transportation services sector provided more than 64,000 jobs in September 2019, while water transportation support services, including cargo handling and other support services, provided more than 97,000 jobs. Employment in both sectors shows a slight upward trend since 1990.

METHODOLOGY, ASSUMPTIONS, AND CONSIDERATIONS

In order for water transportation and support services industries to function effectively, the MTS infrastructure upon which they depend must be maintained and enhanced consistently. According to the ASCE 2017 report cards, the U.S. needs to invest substantially in its inland waterways over the next 20 years. Additional investment is needed for inland and marine ports, together with improvements to complementary transportation infrastructure such as roads and rail systems. These improvements are needed to arrest decay, reduce delays, and to allow American producers to remain competitive in world markets.

This work incorporates earlier assessments of excess costs due to deterioration of water transportation infrastructure. Excess costs are reflected in higher commodity prices for domestically-produced goods, imported goods, and reduced competitiveness of U.S. exports in foreign markets. In the earlier studies, excess cost estimates for various goods sectors were derived using USACE data and FAF projections[1]. These cost parameters were adapted for use in the current study.

In addition to higher costs for domestic shipping, the earlier assessments also accounted for higher costs for receiving goods purchased abroad and for sending U.S. goods to foreign markets. These estimated effects on import prices for goods and on relative prices for U.S. exports also were adapted. The consequence of higher prices for U.S. imports is the reduction of import volumes as import prices rise. Similarly, foreign demand for U.S. exports diminishes as U.S. prices rise relative to foreign prices for similar goods.

The alternatives considered here involve deviations of varying degrees from this downward trajectory into decay, inefficiency, and excess costs. Decline can be offset, to some extent, by higher spending for investment and O&M activities. This spending enhances the existing capital stock and provides a greater, more reliable flow of capital services that facilitates development of more efficient and competitive American industry. These improvements to infrastructure directly and indirectly raise the capacity of the U.S. economy so that the long-run level of GDP rises. Additional benefits may be realized in the short run, particularly during the construction phase, as enhanced investment spending boosts employment and income in construction and supporting industries.

The technique employed in this study, and in earlier studies, is first to develop a baseline projection that incorporates the excess costs that are likely to develop if current policies and spending patterns continue. Because spending in recent history has been inadequate to maintain the quality of infrastructure, and because the quantity of infrastructure has been insufficient to serve the needs of a growing economy, these projections show an economy burdened by excessively high costs and inefficient use of resources. The baseline scenario reflects the full economic costs of degrading water transportation infrastructure. In three alternative scenarios with higher levels of capital and O&M spending for water transportation infrastructure, we examine the economic consequences of increased spending levels leading to reduced transportation costs.

1 For additional details, see ASCE (2012 and 2016).

Scenarios for Improving Infrastructure

Clearly, the needs for improvement are substantial. The present study considers three alternative programs for improving capital and O&M spending. These scenarios differ only in the amounts of spending.

Details for total new spending under the three alternative scenarios are presented in Table 3, while Table 4 displays the additional investment portion and Table 5 shows additional O&M expenditure. These amounts represent the additional amounts of spending assumed for each scenario, where the amounts add to baseline spending levels for infrastructure.

Scenario 1 includes an additional $10 billion in total Federal spending between 2020 and 2030. This follows the Fiscal Year (FY) 2018 infrastructure investment proposal presented by the Administration. That proposal included other forms of infrastructure as well for a total of $1 trillion, with $200 billion in overall new Federal spending that was assumed to leverage an additional $800 billion in combined S&L and private spending[1]. That proposal was included in both the Administration's FY2019 Budget proposal (OMB, 2018) and the FY2020 Budget proposal[2].

1 This implies a total leverage ratio of 4, where $800 billion / $200 billion = 4/1

Because USACE investment in MTS infrastructure amounts to 5% of USACE's infrastructure spending, this study uses 5% as a proxy for the percentage of total Federal spending (i.e. $200 billion) that would be directed towards MTS infrastructure, implying a total of $10 billion in Federal spending. In keeping with Administration assumptions, including the leverage ratio, S&L governments and the private sector contribute $40 billion; we assume that each contributes $20 billion. Total new spending in this scenario thus amounts to $50 billion; the Federal government supplies 20% of funds while S&L governments and private industry together provide 80%.

Scenario 2 is similar to Scenario 1, but it follows an enhanced 2019 infrastructure investment plan discussed between the Administration and Congressional leaders[3]. The proposal doubled envisioned additional infrastructure spending to $2 trillion over ten years. Using the same investment proportions as in Scenario 1, we assume $20 billion in Federal spending going to MTS infrastructure,

2 "Infrastructure 2020 Budget Fact Sheet," www.whitehouse.gov/wp-content/uploads/2019/03/FY20-Fact-Sheet_Infrastructure_FINAL.pdf.

3 "Democrats, Trump Agree to Aim for $2 Trillion Infrastructure Package," www.wsj.com/articles/democrats-trump-agreed-on-2-trillion-infrastructure-package-11556640992.

Table 3. Enhanced Infrastructure Spending
Billions of Dollars

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Scenario 1	**2.95**	**3.67**	**4.21**	**4.85**	**5.28**	**5.57**	**5.40**	**4.97**	**4.60**	**4.33**	**4.17**	**50.00**
Federal	0.59	0.73	0.84	0.97	1.06	1.11	1.08	0.99	0.92	0.87	0.83	10.00
State & Local	1.18	1.47	1.68	1.94	2.11	2.23	2.16	1.99	1.84	1.73	1.67	20.00
Private	1.18	1.47	1.68	1.94	2.11	2.23	2.16	1.99	1.84	1.73	1.67	20.00
Scenario 2	**5.91**	**7.34**	**8.41**	**9.70**	**10.56**	**11.13**	**10.80**	**9.94**	**9.19**	**8.67**	**8.35**	**100.00**
Federal	1.18	1.47	1.68	1.94	2.11	2.23	2.16	1.99	1.84	1.73	1.67	20.00
State & Local	2.36	2.94	3.36	3.88	4.22	4.45	4.32	3.98	3.68	3.47	3.34	40.00
Private	2.36	2.94	3.36	3.88	4.22	4.45	4.32	3.98	3.68	3.47	3.34	40.00
Scenario 3	**20.23**	**25.14**	**28.81**	**33.23**	**36.15**	**38.12**	**36.99**	**34.06**	**31.49**	**29.69**	**28.59**	**342.50**
Federal	4.05	5.03	5.76	6.65	7.23	7.62	7.40	6.81	6.30	5.94	5.72	68.50
State & Local	8.09	10.06	11.52	13.29	14.46	15.25	14.80	13.62	12.59	11.88	11.44	137.00
Private	8.09	10.06	11.52	13.29	14.46	15.25	14.80	13.62	12.59	11.88	11.44	137.00

Source: Study assumptions.

$40 billion in S&L spending, and $40 billion in private spending, for a total of $100 billion in additional spending for MTS infrastructure.

Scenario 3: In contrast to these first scenarios that rely on the Administration's proposals, Scenario 3 instead relies on estimates of needs provided by other parties. The American Association of Port Authorities (AAPA) estimates that $66 billion in Federal investment in seaport infrastructure is needed over ten years[4]. USACE (March 2016) estimated that about $2.5 billion in capital investment is needed for inland and intracoastal infrastructure. Together, these imply a need for total Federal spending of $68.5 billion. As in the Administration's proposals, a substantial role for S&L and private spending is assumed, with both contributing $137 billion in this scenario. In total,

4 American Association of Port Authorities, "Building America's 21st Century Seaport Infrastructure," aapa.files.cms-plus.com/PDFs/AAPA%20Infrastructure%20Infographic.pdf.

Table 4. Enhanced Infrastructure Capital Spending Billions of Dollars

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Scenario 1	**0.77**	**1.28**	**1.56**	**1.90**	**2.00**	**1.97**	**1.55**	**0.97**	**0.51**	**0.21**	**0.05**	**12.76**
Federal	0.15	0.26	0.31	0.38	0.40	0.39	0.31	0.19	0.10	0.04	0.01	2.55
State & Local	0.31	0.51	0.62	0.76	0.80	0.79	0.62	0.39	0.20	0.09	0.02	5.10
Private	0.31	0.51	0.62	0.76	0.80	0.79	0.62	0.39	0.20	0.09	0.02	5.10
Scenario 2	**1.53**	**2.55**	**3.12**	**3.80**	**4.00**	**3.94**	**3.11**	**1.94**	**1.02**	**0.43**	**0.09**	**25.52**
Federal	0.31	0.51	0.62	0.76	0.80	0.79	0.62	0.39	0.20	0.09	0.02	5.10
State & Local	0.61	1.02	1.25	1.52	1.60	1.58	1.24	0.77	0.41	0.17	0.04	10.21
Private	0.61	1.02	1.25	1.52	1.60	1.58	1.24	0.77	0.41	0.17	0.04	10.21
Scenario 3	**5.25**	**8.74**	**10.68**	**13.00**	**13.71**	**13.49**	**10.64**	**6.63**	**3.50**	**1.46**	**0.31**	**87.42**
Federal	1.05	1.75	2.14	2.60	2.74	2.70	2.13	1.33	0.70	0.29	0.06	17.48
State & Local	2.10	3.50	4.27	5.20	5.48	5.40	4.26	2.65	1.40	0.58	0.12	34.97
Private	2.10	3.50	4.27	5.20	5.48	5.40	4.26	2.65	1.40	0.58	0.12	34.97

Source: Study assumptions.

Table 5. Enhanced Infrastructure O&M Spending Billions of Dollars

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Scenario 1	**2.19**	**2.39**	**2.65**	**2.95**	**3.28**	**3.60**	**3.85**	**4.00**	**4.09**	**4.12**	**4.13**	**37.24**
Federal	0.44	0.48	0.53	0.59	0.66	0.72	0.77	0.80	0.82	0.82	0.83	7.45
State & Local	0.88	0.96	1.06	1.18	1.31	1.44	1.54	1.60	1.63	1.65	1.65	14.90
Private	0.88	0.96	1.06	1.18	1.31	1.44	1.54	1.60	1.63	1.65	1.65	14.90
Scenario 2	**4.38**	**4.79**	**5.29**	**5.91**	**6.55**	**7.19**	**7.69**	**8.01**	**8.17**	**8.24**	**8.26**	**74.48**
Federal	0.88	0.96	1.06	1.18	1.31	1.44	1.54	1.60	1.63	1.65	1.65	14.90
State & Local	1.75	1.92	2.12	2.36	2.62	2.88	3.08	3.20	3.27	3.30	3.30	29.79
Private	1.75	1.92	2.12	2.36	2.62	2.88	3.08	3.20	3.27	3.30	3.30	29.79
Scenario 3	**14.99**	**16.40**	**18.13**	**20.23**	**22.45**	**24.63**	**26.35**	**27.42**	**27.99**	**28.23**	**28.28**	**255.08**
Federal	3.00	3.28	3.63	4.05	4.49	4.93	5.27	5.48	5.60	5.65	5.66	51.02
State & Local	5.99	6.56	7.25	8.09	8.98	9.85	10.54	10.97	11.20	11.29	11.31	102.03
Private	5.99	6.56	7.25	8.09	8.98	9.85	10.54	10.97	11.20	11.29	11.31	102.03

Source: Study assumptions.

Table 6. Distribution of Water Transportation Infrastructure Spending(FY2018)

	Construction (Millions)	O&M (Millions)	Total (Millions)	Construction (%)	O&M (%)	Total (%)
Total	756	2,206	**2,962**	25.5%	74.5%	**100.0%**
Coastal	356	1,365	**1,721**	20.7%	79.3%	**100.0%**
Inland	400	841	**1,241**	32.2%	67.8%	**100.0%**

Source: U.S. Army Corps of Engineers (2018) and author's calculations.

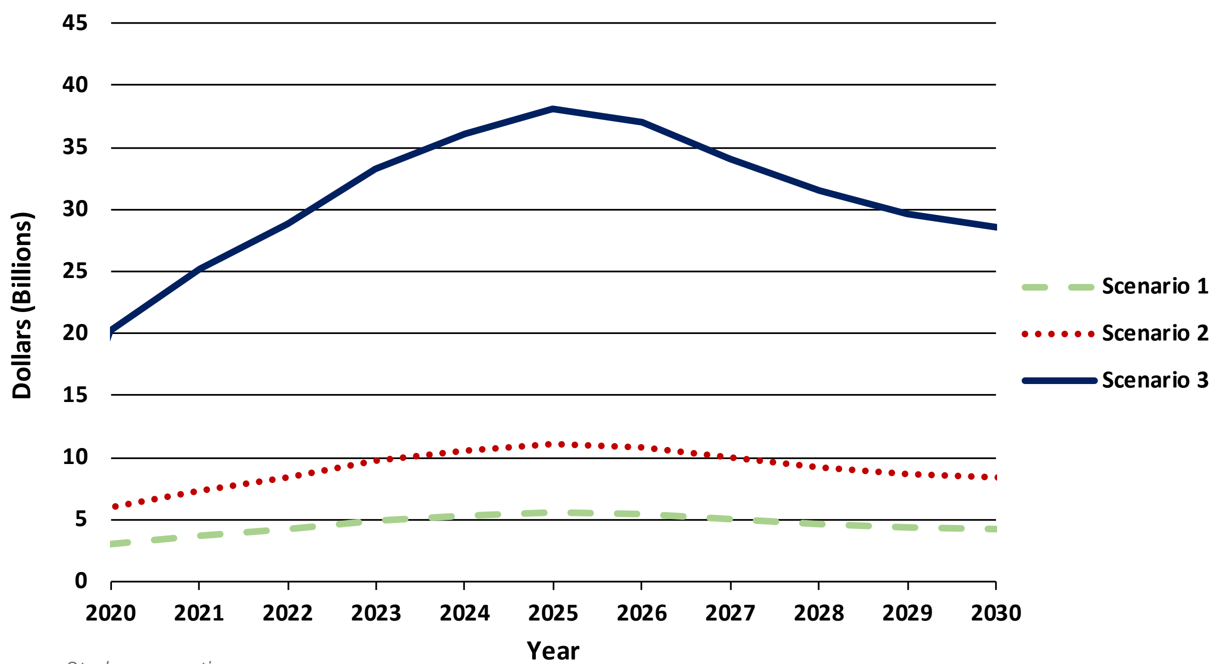
these amount to $342.5 billion in additional MTS spending over ten years.

For each scenario, total funding is distributed among capital and O&M expenditure. Table 6 shows the distribution of spending between capital expenditure and O&M expenditure by the USACE in FY2018. It shows that 25.5% of total spending went to investment while 74.5% went to O&M. We assume that these proportions will hold in each of the three scenarios and that they also apply to S&L and private spending.

In review, Table 3 through Table 5 display the implications of these assumptions in the construction of three alternative scenarios. In each, cumulative spending is consistent with the levels specified for each scenario. The distribution of spending over time is indicated in the tables, and the distribution between capital and O&M expenditure is given in Table 6. The Federal, S&L, and private spending shares are 20%, 40%, and 40%, respectively. Table 3 shows the implied levels of total spending (illustrated in Figure 11), while Table 4 reports capital expenditure and Table 5 shows O&M spending.

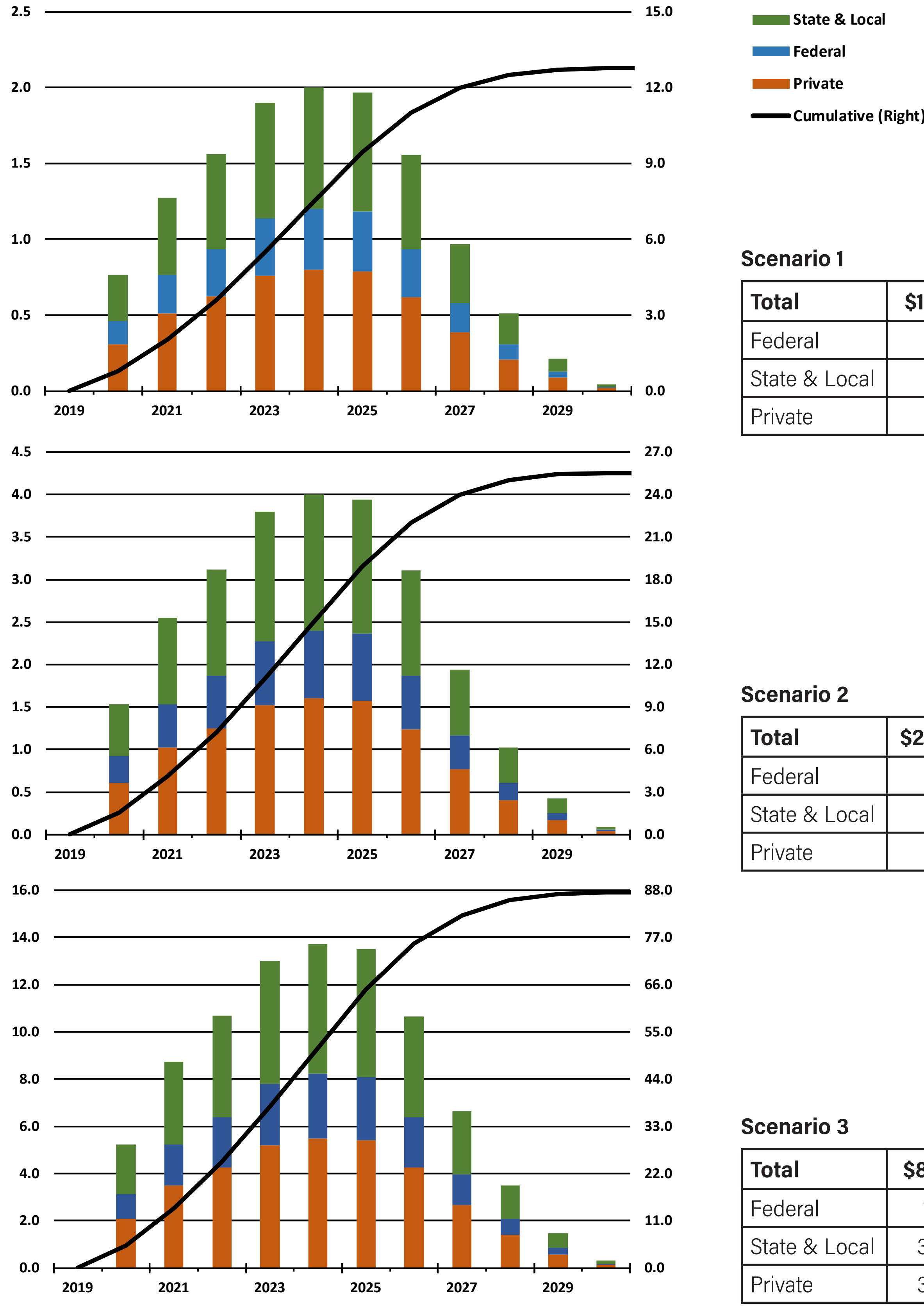
The economic effects of increased capital spending depend not only on the total amount of spending but on the distribution of spending over time. Figure 12 shows capital expenditure trajectories for each scenario, with the construction phase extending over 11 years, from 2020 through 2030. Trajectories follow a modified version of details outlined in the Administration's 2019 proposal. In each scenario, annual spending peaks in 2025. Figure 12 displays

Figure 11. Nominal Total Expenditure Enhancement (2020-2030)



Source: Study assumptions.

Figure 12. Capital Spending (2019-2030)
Billions of Dollars



Scenario 1

Total	$12.76
Federal	2.55
State & Local	5.10
Private	5.10

Scenario 2

Total	$25.32
Federal	5.10
State & Local	10.21
Private	10.21

Scenario 3

Total	$87.42
Federal	17.48
State & Local	34.97
Private	34.97

both cumulative total capital expenditure and annual capital spending by sector; these annual amounts also are shown in Table 4.

Additional spending for O&M is devoted partially to existing infrastructure and partially to serve new assets. Once the new capital program is completed, we assume that 50% of new O&M funds will go to each. During the construction phase, a constant share will go to serve existing capital, and new O&M spending associated with new assets will rise in proportion to cumulative capital spending. The resulting trajectory for O&M spending also is indicated in Table 5.

Capital spending reverts to baseline levels after the construction phase concludes in 2030, while O&M spending remains higher in each scenario. From 2031 through the forecast horizon, we assume that O&M nominal spending will exceed baseline levels by the amount projected for 2030. Cumulative O&M spending from 2020-2030 thus is in the amount specified for each scenario, while additional O&M spending each year from 2031-2045 exceeds baseline spending by the amounts of spending for 2030 shown in Table 5 (e.g. for Scenario 1, annual O&M spending is $4.1 billion above baseline for 2031-2045).

Table 7 shows that the Federal government provided 37.4% of total funding for water transportation and water resource infrastructure in 2017, with 37.0% spent directly and 0.4% capital transfers to support S&L capital spending. S&L governments provided the remaining 62.7% of funding (CBO, October 2018). This suggests little financial interaction between Federal and S&L programs for these types of public infrastructure. The Federal government provided no support for S&L O&M spending and little support for S&L capital spending in 2017. While new policy could change this pattern, it would be a significant break from past policies. Using these figures for guidance, each scenario includes a small amount of Federal support for S&L construction spending.

Infrastructure assets include several major components: structures, equipment, intellectual property, and real estate. We calculate 2016 S&L spending shares for structures (75%), equipment

Table 7. Public Funding of Water Transportation and Water Resources Infrastructure

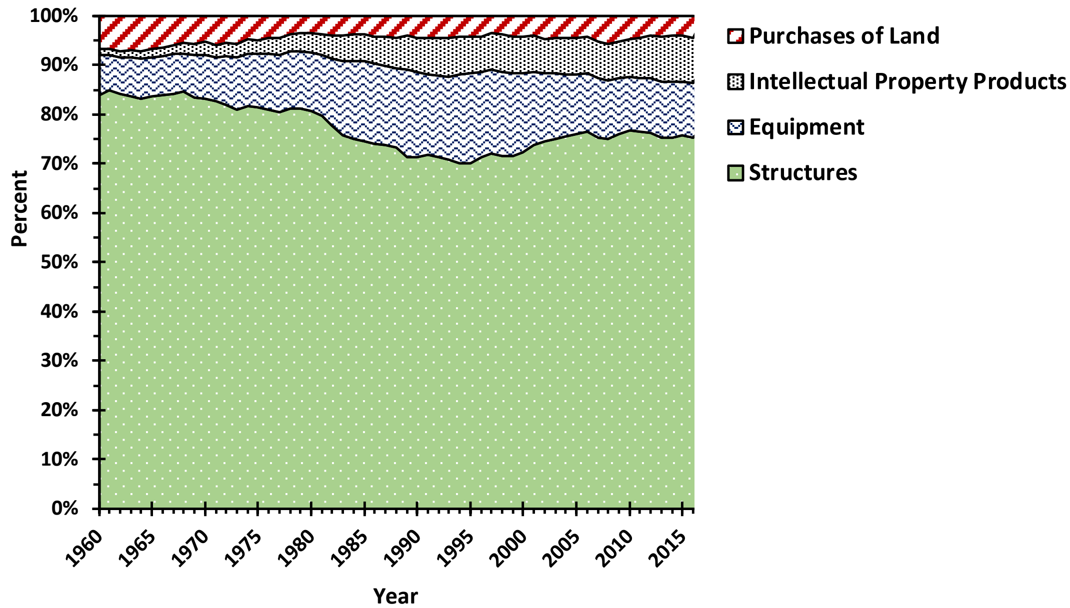
	2017 Funding (Millions)	Percentage (%)
Total	**$38,889**	**100.0%**
Federal Direct	$14,380	37.0%
Federal Grants	$141	0.4%
S&L Funding	$24,368	62.7%
Federal Direct	**$14,380**	**100.0%**
Capital	$5,484	38.1%
O&M	$8,896	61.9%
Federal Grants	**$141**	**100.0%**
Capital	$141	100.0%
O&M	$0	0.0%
S&L Funding	**$24,368**	**100.0%**
Capital	$6,028	24.7%
O&M	$18,339	75.3%
S&L Total Spending	**$24,509**	**100.0%**
Capital	$6,170	25.2%
O&M	$18,339	74.8%

Source: Congressional Budget Office (2018)

(11%), intellectual property (9%), and real estate (5%); Figure 13 portrays these shares from 1960 through 2016. We assume that these shares calculated from overall S&L capital budgets apply to infrastructure capital spending in particular, and we use these S&L spending shares to divide components of Federal and private spending as well. Using the total capital spending amount for each entity specified in the alternative scenarios as shown in Table 4, these shares imply the amounts spent on each component of capital expenditure. These, then, are used to construct spending by major type in each alternative scenario.

The national accounts include public spending for O&M activities in the Federal nondefense and S&L consumption spending categories. Additional spending for O&M activities, as summarized in Table 5, allows increased labor compensation and purchases of durable goods, nondurable goods, and services; these are components of government consumption. Labor compensation is adjusted in the scenarios by modifying the baseline projection

Figure 13. State & Local Spending Shares by Types of Assets (1960-2016)



Source: Census Bureau; Bureau of Economic Analysis; and author's calculations.

of government employment levels, and purchases of goods and services are adjusted directly.

We assume that capital spending offsets deterioration in infrastructure that otherwise would occur. These offsets depend on the cumulative amount of capital spending, and deterioration is derived from the excess cost projections calculated by ASCE (2012). The benefits of new infrastructure thus follow the cumulative amount of real capital spending (i.e. the quantity of new capital stock, taking into account the effects of changing prices for investment). However, because capital deteriorates over time, the benefits initially offered by new capital dissipate slowly. Table 8 displays BEA estimates of depreciation rates[5] for various types of infrastructure. The two most relevant are rates for Other Transportation (2.37%) and Conservation and Development (2.25%) assets, and so we assume that relevant infrastructure will decay at a rate of 2.30%. While benefits of new infrastructure will be realized as new capital is added, the benefits then will slip away slowly after construction is completed.

5 See "BEA Depreciation Estimates," apps.bea.gov/national/pdf/BEA_depreciation_rates.pdf.

Finally, we assume that additional public spending is financed by debt, with no changes to tax rates or fees. While revenue flows depend on the size of the economy and the economy is enhanced by new spending, the scenarios considered here do not include policy changes intended to recover new capital and O&M costs.

Table 8. Depreciation Rates Percentages, Geometric Rate of Decay per Year

Type of Asset	Rate of Depreciation
Local transit	2.37%
Air transportation	2.37%
Other transportation	2.37%
Other land transportation	2.37%
Water supply	2.25%
Sewage and waste disposal	2.25%
Highway and Conservation and development	2.25%

Source: Bureau of Economic Analysis

THE ECONOMIC AND INDUSTRY IMPACTS OF ENHANCED MTS INFRASTRUCTURE SPENDING

The CBO (Shirley, 2017) reports two primary effects of Federal investment. First comes a short-run boost to overall demand, with higher spending spurring faster growth and higher employment. Enhanced private-sector labor productivity comes later and extends into the long run, boosting production capacity and economic competitiveness. The modeling work shown here, addressing spending on MTS infrastructure by S&L governments and the private sector as well as the Federal government, illustrates these short-run demand effects and long-run supply effects.

This study links industry-level cost effects and the national economy. We use information drawn from ASCE (2012), as was described earlier. In particular, these reports compiled and synthesized a large volume of data on the conditions, costs, and investment requirements of U.S. infrastructure. The industry-level cost implications of deficient infrastructure were used in the Inforum LIFT model[1] to show the long-term economic consequences of allowing the continuing decline of American infrastructure.

This report leverages the industry-level cost information to illustrate how enhanced infrastructure investment and O&M spending can benefit the economy. Three potential scenarios to improve MTS infrastructure were considered; these scenarios were described earlier. A baseline "low investment" scenario, or business-as-usual case, was developed that is similar to the ASCE deficient investment scenarios. This baseline shows the economic effects of continued under-investment with consequent inefficiencies and rising costs.

The competitive enhancement allowed by better MTS infrastructure accrues to industries in proportion to their direct and indirect dependence on the MTS. Manufacturers that depend intensively on water for receiving supplies and delivering products see substantial cost reductions. The Inforum LIFT model used in this study is well-suited to tracing the long-run cost and competitiveness impacts of higher-quality infrastructure. In the model, the benefits of improved infrastructure first are calculated at the industry level, either as labor productivity gains or as other cost reductions. In turn, the model simulations show that these cost savings are passed to their customers both at home and abroad, allowing domestic producers to gain advantages over foreign competitors.

In addition, the model provides a meaningful accounting of consumer transactions. In many cases, the benefits of improved infrastructure are realized through explicit purchases by consumers, and savings due to reduced transportation costs can be spent on other goods and services. The net impact of these forces raises real output, employment, and income over the long run, though the supply-side benefits of enhanced infrastructure spending will take time to materialize. Higher spending on infrastructure can boost the economy in the short run as well, though the extent of such boosts depends on current economic conditions and the details of the spending programs.

The LIFT model indicates the extent of "multiplier" effects of increased expenditures over the short term. Greater spending on infrastructure increases overall demand in the economy and tends to stimulate higher growth. However, the extent of the multiplier effects depends on economic conditions, as are modeled in the baseline scenario. If the economy is fully employed, then increased government expenditures can "crowd out" private activity to some degree, lessening the increase in growth that otherwise might result. Therefore,

1 Additional information about the Inforum LIFT model is presented in Appendix B.

the multiplier effect could be relatively small if, for example, the unemployment rate already is low so that most workers needed to support the new spending program either must be pulled from other jobs or persuaded to join the labor force.

In such cases, additional government spending tends to spur inflation, raise relative prices of American goods and services relative to foreign counterparts, and thus raise imports and reduce exports. Higher inflation and debt financing tend to raise interest rates as well, which discourages borrowing for housing, auto purchases, and other items. These reduce the potential benefits of higher government spending. On the other hand, when the economy has substantial idle capacity and underemployment, the crowding-out effect may be minimal. Several studies have shown that so long as interest rates and inflation remain low, then the fiscal multipliers are especially high[2]. Multipliers may be especially large for infrastructure spending during times of high economic slack (Leduc & Wilson, 2012).

2 See Blanchard & Leigh (2013) and DeLong & Summers (Spring 2012).

RESULTS

The three alternative model simulations with higher capital and O&M spending include immediate and significant boosts to MTS infrastructure spending, compared to the baseline, where higher capital spending extends through 2030 and higher O&M spending is maintained in the long term. In these alternative scenarios, improved infrastructure quantity and quality reduces transportation costs for businesses and consumers across the economy.

Across the three scenarios, increases to infrastructure spending are relatively small, though they begin in an economy with historically low unemployment rates and seemingly few available construction workers. The extra spending stimulates demand for construction and supporting industries such as materials and equipment manufacturing, but some business is lost to a wider trade deficit and deferred spending. Still, crowding is not complete, and economic growth and employment are enhanced even in the short term. Over the long term, however, supply forces—available labor, capital (including infrastructure), and productivity—determine the level of aggregate output. It is precisely because the extra infrastructure investment enhances the productive capacity of the economy that it delivers durable benefits over the longer term.

Details of enhanced nominal spending are shown in Tables 3 through 5, with total cumulative spending through 2030 for Scenario 1 is $50 billion, for Scenario 2 is $100 billion, and for Scenario 3 is $342.5 billion. These amounts are in excess of spending included in the baseline scenario. Table 9 presents spending totals through 2045 for each scenario in real (inflation-adjusted 2012 dollars) quantities and the proportion of each quantity to the level of real GDP in the baseline scenario.

The LIFT model's linkages among industries and from industries to consumers provide a framework to assess how improved infrastructure affects the whole economy. Enhancements to spending begin in 2020, initially ranging from 0.013% to 0.086% of baseline real GDP, as shown in Table 9. These proportions rise to a range of 0.021% to 0.141% of real GDP by 2025; amounts then decline through 2030 as capital spending dwindles. O&M spending continues through 2045, though the amounts are constant in nominal terms after 2030; real O&M quantities diminish slowly in these years as O&M prices rise gradually.

Table 9. Real Infrastructure Expenditure (2020-2045)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Billions of 2012$										
Scenario 1	2.31	2.81	3.15	3.56	3.78	3.88	2.48	2.16	1.91	1.69
Scenario 2	4.61	5.62	6.29	7.11	7.56	7.77	4.96	4.32	3.82	3.38
Scenario 3	15.81	19.25	21.56	24.36	25.87	26.60	17.00	14.79	13.08	11.58
Percentage of Baseline GDP										
Scenario 1	0.012	0.014	0.016	0.017	0.018	0.018	0.011	0.008	0.007	0.005
Scenario 2	0.024	0.028	0.031	0.035	0.036	0.036	0.021	0.017	0.013	0.011
Scenario 3	0.081	0.097	0.107	0.118	0.123	0.124	0.072	0.057	0.046	0.037

Source: Study assumptions and LIFT Modeling Analysis by Inforum.

Economic Impacts of GDP

Table 10 shows a summary of macroeconomic modeling results for real GDP and its major components. Because the amounts of additional spending are relatively small, even in Scenario 3, the effects on annual GDP also are relatively small. These effects range in 2020 from $2.7 billion to $13.6 billion in 2012$ dollars. The effects rise through 2025 along with spending rates, reaching $8.8 billion to $37.1 billion in additional GDP. In contrast to spending levels, GDP effects slip only gradually after 2025. The gradual decline reflects the transition from short-run GDP effects due to enhanced demand to long-run GDP effects due to enhanced capacity and reduced costs. Even in 2045, long after the capital improvement phase concludes and only enhanced O&M spending continues, real GDP remains relatively high in proportion to the baseline projection. While the additional O&M spending beyond 2030 does provide some continuing demand-side support to GDP, the supply-side effects on GDP are substantial and become more pronounced in those years.

These results are illustrated in Figure 14 for Scenario 3, which reflects the largest assumed amount of infrastructure spending. The total enhanced real spending curve reflects an initial surge of capital outlays in the early years of the program, followed by diminishing incremental investments as the construction phase winds down. In the later years, infrastructure spending predominately consists of O&M. Because nominal O&M spending is constant beyond 2030, real O&M spending levels diminish slowly. Enhancement of GDP is greatest shortly after the conclusion of the capital phase. In the long run, GDP gradually moves toward baseline levels as real O&M spending diminishes and as the capital stock depreciates. Despite the ultimate decay of public capital as it ages, the rate of decline in annual GDP gains above the baseline (i.e. the rate of convergence to the baseline trajectory) is minor, averaging just -0.4% per year from 2030-2045 in Scenario 3. Lagged effects of the capital program and O&M on labor productivity continue to work their way through the economy, offsetting the economic hindrance caused by depreciating public capital.

Figure 15 illustrates the effect on the overall economy by comparing cumulative GDP gains above the baseline to cumulative spending; the ratio implies a long run multiplier for each scenario – in other words, the "bang for the buck". Initial effects on GDP are muted because increased MTS investment lowers the amount of resources available for private economic activity, as described earlier in the report (crowding). In the longer run, however, the cumulative effect of sustained infrastructure spending and buildup of capital assets increases demand for goods and services and expands the productive capacity of the entire economy. As a result, by 2045 infrastructure investments could produce economy-wide returns from about $2 to nearly $3 per every $1 spent, after adjusting for inflation.

The results show that trade with foreign counterparts increases significantly in the long run, though capacity constraints in the short run mean reduced exports and higher imports (Table 10, "Real Net Exports"). The trade gap thus widens through the first part of the construction phase, but as spending begins to subside and economic capacity rises, the trade gap begins to narrow.

Since private business becomes more profitable when public infrastructure is enhanced, private investment in equipment, nonresidential structures, and intellectual property tends to complement public infrastructure investment. Private investment thus is significantly higher in the short term. In 2025, private nonresidential fixed investment ranges from $2.3 billion to $9.9 billion above the baseline level. While some of this additional private investment spending is assumed as private participation in infrastructure improvement, a significant portion of additional investment spending comes as other industries react to increased sales and profitability.

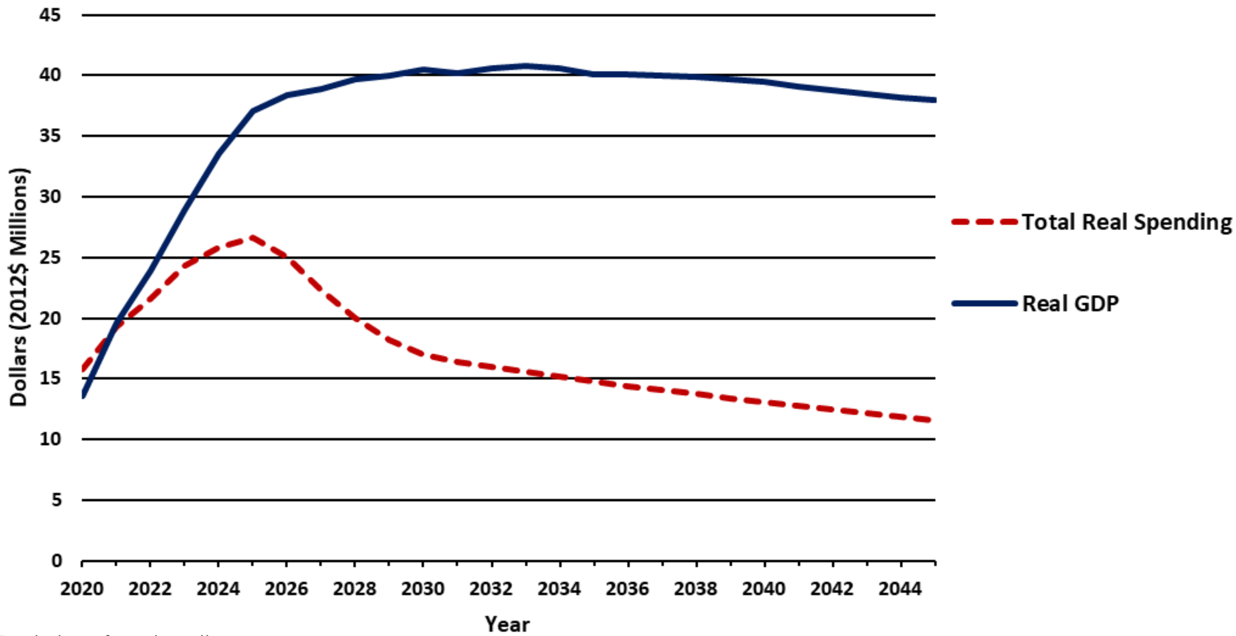
The greatest part of GDP is personal consumption spending. With support of higher incomes due to increased employment, higher wages, and enhanced capital income such as dividends, consumption spending rises between $5.3 billion and $12.0 billion in 2025. Residential investment increases $0.4 billion to $1.5 billion in 2025 (Table 10). Although consumption and investment levels

Table 10. Real GDP by Final Demand Category (2020-2045)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Gross Domestic Product	**19,464.6**	**19,852.6**	**20,220.4**	**20,609.9**	**21,012.4**	**21,415.7**	**23,533.4**	**25,893.8**	**28,450.9**	**31,208.9**
	2.7	3.8	5.0	6.3	7.7	8.8	7.9	7.3	7.3	7.6
	4.7	6.6	8.5	10.6	12.9	14.4	15.6	14.2	14.0	13.9
	13.6	19.5	23.9	29.0	33.5	37.1	40.5	40.1	39.4	37.9
Personal Consumption Expenditures	13,543.1	13,823.1	14,093.9	14,370.7	14,650.9	14,932.2	16,382.0	17,978.3	19,707.0	21,576.2
	1.1	1.5	2.5	3.4	4.4	5.3	4.1	2.3	1.7	1.5
	1.2	1.9	3.1	4.4	5.7	6.8	7.6	4.3	2.9	1.8
	2.2	4.3	6.5	8.4	10.3	12.0	16.0	10.7	7.9	5.9
Gross Private Domestic Investment	3,534.3	3,642.3	3,743.4	3,854.2	3,975.7	4,099.0	4,764.3	5,516.7	6,341.6	7,297.7
	0.7	1.4	1.7	2.0	2.5	2.7	1.8	2.1	1.9	1.8
	1.3	2.4	2.9	3.5	4.3	4.5	3.6	3.4	3.4	3.0
	3.0	6.7	7.9	9.5	11.0	11.7	9.4	10.2	10.2	8.9
Nonresidential Fixed Investment	2,882.5	2,959.3	3,044.0	3,125.9	3,213.0	3,308.5	3,811.8	4,407.1	5,096.3	5,894.1
	0.4	1.2	1.4	1.7	2.1	2.3	1.6	1.6	1.5	1.5
	0.7	2.1	2.4	3.0	3.7	3.9	3.2	2.9	2.8	2.5
	2.2	5.8	7.0	8.3	9.5	9.9	6.9	7.2	6.9	5.7
Residential Investment	606.3	632.8	649.1	675.2	704.8	731.5	875.4	1,020.8	1,154.1	1,310.8
	0.1	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.3
	0.2	0.3	0.4	0.5	0.5	0.6	0.4	0.5	0.5	0.4
	0.4	0.7	0.9	1.0	1.3	1.5	1.9	2.4	2.5	2.2
Real Net Exports (Billions 2012$)	-967.6	-976.1	-986.8	-999.5	-1,015.5	-1,032.0	-1,108.4	-1,218.7	-1,323.6	-1,484.0
	-0.8	-1.2	-1.6	-1.9	-2.2	-2.4	0.0	1.4	2.4	3.3
	-1.1	-1.9	-2.3	-2.8	-3.1	-3.2	0.4	3.6	5.4	7.3
	-3.0	-5.8	-7.1	-8.0	-8.3	-8.1	0.9	8.2	12.1	14.5
Exports	2,696.0	2,779.8	2,865.6	2,956.4	3,046.7	3,139.2	3,640.7	4,220.6	4,916.9	5,716.0
	-0.1	-0.2	-0.3	-0.3	-0.1	0.3	4.1	7.4	10.5	13.6
	-0.2	-0.3	-0.3	-0.2	0.2	0.9	8.4	15.3	21.9	28.0
	-0.4	-0.5	-0.3	0.6	2.3	5.1	29.0	48.0	64.3	78.9
Imports	3,663.6	3,756.0	3,852.4	3,956.0	4,062.2	4,171.2	4,749.1	5,439.3	6,240.5	7,200.0
	0.6	0.9	1.3	1.6	2.1	2.6	4.1	5.9	8.1	10.3
	0.9	1.6	2.0	2.6	3.3	4.1	8.0	11.7	16.5	20.8
	2.6	5.3	6.8	8.6	10.6	13.2	28.1	39.8	52.2	64.4
Government Consumption & Investment	3,321.7	3,332.3	3,340.8	3,357.5	3,376.6	3,394.8	3,500.3	3,661.7	3,837.4	4,028.5
	1.6	1.9	2.2	2.6	2.8	2.9	1.9	1.5	1.3	1.0
	3.1	3.9	4.5	5.1	5.5	5.8	3.9	3.1	2.6	2.1
	10.8	13.3	15.3	17.6	19.0	19.8	13.3	10.7	8.8	7.3
Federal Defense	745.6	739.5	732. 7	728.8	726.9	725.1	731.3	751.9	774.7	799.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Nondefense	497.7	492.8	486.2	485.2	484.6	484.4	491.5	510.5	532.6	559.2
	0.5	0.7	0.8	0.9	1.0	1.0	0.7	0.6	0.5	0.4
	1.1	1.3	1.5	1.7	1.9	2.0	1.4	1.2	1.0	0.8
	3.6	4.5	5.2	6.0	6.5	6.9	4.9	3.9	3.3	2.7
State & Local	2,075.2	2,096.1	2,117.2	2,138.2	2,159.1	2,178.5	2,268.4	2,387.7	2,515.7	2,652.8
	1.0	1.3	1.5	1.7	1.8	1.9	1.2	1.0	0.8	0.6
	2.1	2.5	2.9	3.3	3.6	3.7	2.4	1.9	1.6	1.3
	7.1	8.7	10.0	11.4	12.3	12.7	8.4	6.7	5.5	4.6

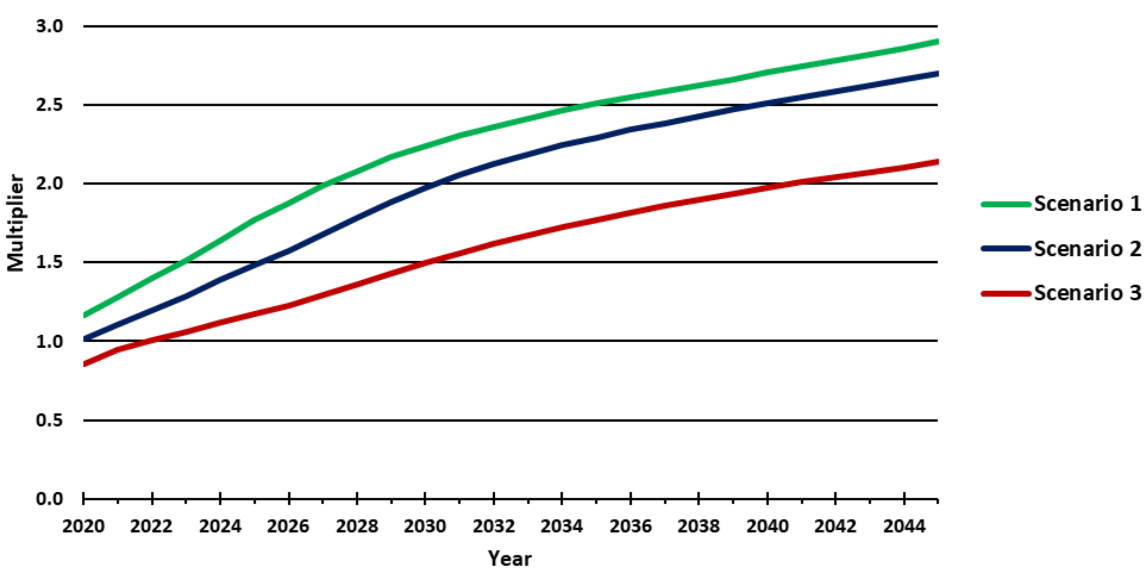
Table 10 (left) Baseline levels are shown first in billions of 2012 dollars. Results for Scenarios 1-3 are shown next as deviations from baseline, except where noted. The table presents groups of four rows, beginning with a group of results for real GDP. First, the level of GDP is shown for the baseline scenario in 2012 dollars. Next, results for Scenario 1 are shown as the differences between the alternative case and the low-investment base case. The third and fourth items present corresponding results for Scenarios 2 and 3, respectively. In some cases, results for the alternative scenarios are shown in alternative measures such as percentage differences in the levels relative to the baseline levels; such cases are identified in the tables. After the results for real GDP come the major components of GDP, including personal consumption, investment, international trade, and government spending.
Source: LIFT Modeling Analysis by Inforum.

Figure 14. Real Spending and Real GDP Effects (2020-2045)



Deviations from baseline.
Source: Study assumptions and LIFT Modeling Analysis by Inforum.

Figure 15. Real GDP Multiplier Effects (2020-2045)



Source: LIFT Modeling Analysis by Inforum.

move gradually toward baseline levels in later years, GDP and its components remain at elevated levels through the 2045 forecast horizon.

As shown in Table 10, the trade gap narrows in the long run after widening during the height of the capital program. In the long run, however, U.S. producers become more competitive in the trade of goods and services so that the trade gap narrows. The current account balance, which includes the value of net trade volumes plus other net international financial flows, also shows improvement. Though net exports and the current account balance remain large and negative, both nonetheless become smaller. The current account balance in proportion to nominal GDP also becomes smaller as the financial position of the U.S. improves.

Employment and Labor Productivity

On the supply side, a rise in the level of potential GDP (a measure of the economic capacity) is supported both by greater employment and by increased labor productivity. In the short run, infrastructure investment boosts jobs between 54.7 thousand and 182.5 thousand jobs in 2025, depending on the scenario; this is shown in Table 11. These numbers fall over time as the labor productivity effects of better infrastructure take hold and as stimulus wanes, but continuation of higher O&M spending and improved competitiveness mean that more workers are employed in the long run. Increased spending while unemployment rates already are low raises inflation and interest rates in the short run, but these pressures subside as the economy adjusts.

Overall productivity growth initially fluctuates as the production mix of various industries varies. Because the initial employment formation is skewed toward construction (as seen in Table 15), a sector with relatively low productivity growth, aggregate labor productivity growth is restrained. At the same time, higher production by steel producers and other high-productivity manufacturing sectors boosts overall productivity, but opposing effects induce little change from baseline in the early years. Productivity and output across industries are enhanced over the longer term, however, mainly through the positive productivity effects of better infrastructure.

The best indicator of the net welfare gain provided by enhanced investment is real disposable income for households. This statistic includes the gain of income resulting directly from increased economic activity and efficiency (as measured by GDP), and it also measures the enhancement to purchasing power due to lower prices and lower need for consumer direct and indirect expenditures on transportation. The benefit of infrastructure spending is increased real disposable income above baseline levels, for example ranging between $9.6 billion and $39.7 billion (in 2012 dollars) in 2030, or between $70 and $292 in 2030 for every household. Improvements to infrastructure thus imply small but helpful gains in real household income that allow increased spending on personal consumption and residential investment.

Table 11 (Right). Prices, Interest Rates, Employment, and Income (2020-2045)

Baseline levels are shown first in billions of dollars. Results for Scenarios 1-3 are shown next, with prices as percentage deviations and other concepts as deviations from baseline. *Source: LIFT Modeling Analysis by Inforum.*

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Price Indicators (2012 = 100)										
GDP Deflator (Baseline)	114.9	117.3	119.9	122.4	125.0	127.6	141.8	157.4	174.0	192.3
Scenario 1	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00
Scenario 2	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.02	0.01	0.00
Scenario 3	0.00	0.02	0.03	0.03	0.04	0.04	0.05	0.02	0.01	0.00
PCE Deflator	112.3	114.9	117.5	120.0	122.7	125.4	140.1	156.2	174.1	194.0
	0.00	0.01	0.01	0.01	0.01	0.01	0.01	-0.01	-0.02	-0.03
	0.01	0.01	0.02	0.02	0.02	0.02	0.01	-0.01	-0.03	-0.05
	0.02	0.04	0.04	0.04	0.04	0.04	-0.00	-0.04	-0.06	-0.08
Exports Deflator	101.2	102.9	104.8	106.4	108.1	110.0	119.6	129.7	140.1	151.0
	0.01	0.01	0.01	0.01	0.01	0.01	0.00	-0.01	-0.01	-0.02
	0.01	0.02	0.02	0.02	0.02	0.02	-0.01	-0.02	-0.03	-0.03
	0.04	0.05	0.06	0.05	0.05	0.04	-0.03	-0.04	-0.05	-0.06
Interset Rates (Annual Average)										
Treasury Bills, 3-Month	1.9	2.2	2.6	2.8	2.9	2.9	3.0	3.0	3.1	3.1
	0.00	0.01	0.01	0.01	0.02	0.02	0.01	-0.00	-0.00	-0.00
	0.01	0.01	0.02	0.02	0.03	0.03	0.01	-0.00	-0.00	-0.00
	0.02	0.03	0.04	0.05	0.06	0.06	0.02	-0.00	-0.00	-0.00
Treasury Bonds, 10-Year	2.6	3.0	3.2	3.5	3.6	3.6	3.9	4.0	4.3	4.3
	0.00	0.00	0.01	0.01	0.01	0.01	0.00	-0.00	-0.00	-0.00
	0.00	0 .01	0.01	0.01	0.02	0.02	0.01	-0.00	-0.00	-0.00
	0.01	0.02	0.02	0.03	0.03	0.03	0.02	-0.00	-0.00	-0.00
Labor Force, Employment, and Productivity										
Civilian Labor Force (Thousands)	164,980.3	166,223.3	167,262.0	168,476.0	169,616.7	170,322.4	173,480.7	177,169.3	180,751.4	184,239.7
	3.0	6.1	9.2	12.3	15.5	18.6	34.7	31.0	27.1	27.6
	4.5	9.1	13.7	18.4	23.2	27.9	52.0	48.7	45.2	46.1
	12.0	24.2	36.5	49.0	61.7	74.3	138.8	137.3	135.5	138.2
Total Jobs (Thousands)	166,002.9	166,657.7	167,510.9	168,385.4	169,375.2	170,404.3	173,798.1	177,498.8	181,105.4	184,606.8
	19.2	29.1	34.9	42.3	49.1	54.7	41.2	31.5	27.9	27.3
	31.5	48.3	59.0	70.8	82.6	90.9	71.5	49.6	45.5	45.0
	80.1	108.6	133.8	156.3	174.3	182.5	165.8	137.2	134.3	136.4
Total Labor Productivity (2012$/Hour)	70.4	71.3	72.3	73.4	74.4	75.4	81.3	87.6	94.5	101.8
	0.002	0.000	0.002	0.003	0.004	0.005	0.003	0.004	0.006	0.008
	0.001	-0.000	0.001	0.003	0.004	0.005	0.007	0.010	0.013	0.015
	0.002	-0.001	-0.001	0.001	0.004	0.007	0.017	0.026	0.032	0.033
Unemployment Rate	3.8	4.2	4.3	4.6	4.7	4.6	4.6	4.6	4.6	4.6
	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.00	-0.00	-0.00	0.00
	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.01	-0.00	-0.00	0.00
	-0.04	-0.05	-0.06	-0.06	-0.07	-0.06	-0.02	-0.00	0.00	0.00
Disposable Personal Income										
Disposable Income (Billions)	17,081.3	17,848.3	18,687.5	19,536.6	20,414.2	21,290.5	26,012.8	31,669.5	38,490.2	46,899.2
	2.1	4.4	6.8	9.3	12.1	14.7	17.0	14.0	14.2	14.3
	3.9	7.8	11.9	16.3	21.2	25.2	30.2	25.1	25.5	26.3
	11.5	21.9	31.9	41.3	51.0	58.7	69.2	65.6	72.1	79.9
Real Disposable Income (Billions 2012$)	15,204.0	15,537.0	15,908.3	16,280.4	16,643.6	16,978.9	18,569.8	20,271.5	22,110.8	24,175.2
	1.3	2.8	4.5	6.2	8.0	9.6	11.1	10.5	12.2	15.4
	2.3	4.7	7.6	10.5	13.7	16.3	20.3	18.7	20.7	24.5
	6.5	12.9	20.3	27.5	34.2	39.7	49.9	49.4	54.2	60.8
2012$ per Household	116,972.6	118,469.6	120,233.3	121,972.5	123,603.9	124,998.6	131,216.6	138,295.1	146,499.4	156,329.6
	10.4	21.2	33.7	46.1	59.4	70.7	78.5	71.6	80.9	99.4
	17.6	35.6	57.6	79.0	101.9	120.4	143.8	127.7	137.2	158.5
	49.8	98.5	153.7	205.7	253.8	292.4	352.7	336.7	358.8	393.0

Fiscal Balances

Table 12 displays implications for fiscal balances and international accounts. Although no changes to tax policy is assumed in these scenarios, higher levels of spending and production do lead to higher revenue amounts collected by Federal and S&L governments. Federal deficits and debt initially rise as increased spending (including higher interest payments to fund increased debt levels) outpaces increases in revenue.

In later years, though, Federal borrowing and debt fall below baseline projections, with reductions apparent in levels and in proportion to GDP. Reduced debt in proportion to GDP is especially important, as this ratio indicates the manageability of debt loads. S&L borrowing and debt loads in the baseline are substantially lower than for its Federal counterpart. Enhanced long-run O&M spending implies slightly higher S&L borrowing and debt, but debt levels in proportion to GDP fall in the long run, albeit slightly more slowly than in the baseline case.

Industry Results

Table 13 shows the impact of higher infrastructure investment on real gross output for major industries of the economy. These measures show the direct and indirect effects of higher infrastructure spending on industry production levels after adjusting for inflation. The construction industry is helped most in the high investment scenarios, but the positive effects of better infrastructure are spread throughout the economy. Transportation service industries also enjoy a boost to real output as they capitalize on better infrastructure to move more merchandise. Manufacturing and mining are helped too, in part due to their production of construction materials, and delivery of these products to construct new infrastructure requires additional trucking, rail, and other transportation services. Agriculture and forestry realize long-run gains due to higher household consumption spending, other additional private construction spending, and especially due to greater net exports.

Table 14 shows the boost to exports across the economy. The figures show differences in real exports between the low investment baseline and the alternative scenarios, in 2009 dollars. By 2030, the Nation exports between $3.2 billion and $22.6 billion more than in the baseline, depending on the scenario. These figures rise further by 2045, ranging between $10.6 billion and $61.4 billion above baseline export levels, including additional exports of goods and services. Goods-producing industries realize greater proportional benefits, while exporters of services gain smaller amounts. Exports for mining, manufacturing, and agriculture sectors rise most in the long run, though many sectors see moderate declines in the short run. Additional benefits of exports due to higher transportation, wholesale trade, and royalty income are associated directly with production and exports of goods. Services sectors realize long-run export increases as well, in part because greater domestic sales in earlier years spur higher capital spending that leads to greater production capacity.

Finally, Table 15 shows the employment impacts for major industries. While most industries add jobs to facilitate increased production, employment in transportation services falls relative to the baseline. This signifies the major benefit of better infrastructure: the productivity of moving goods and passengers expands sufficiently that employment in the sector falls despite increased transportation volumes. These workers then become available to work in other sectors. Widespread enhancement of labor productivity means that employment requirements due to increased production volumes are reduced. Unit labor costs tend to be lower, though somewhat higher wage rates mean that the benefits of labor savings are divided between workers and business owners.

Table 12. Fiscal Balances (2020-2045)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Nominal Fiscal Balances (Billions of Dollars)										
Federal Net Borrowing	**1,204.7**	**1,286.4**	**1,370.0**	**1,413.2**	**1,454.2**	**1,539.4**	**1,806.3**	**2,045.7**	**2,403.9**	**3,001.3**
	0.3	0.7	1.2	1.8	2.4	2.7	1.8	-1.3	-3.1	-5.5
	0.7	1.6	2.7	3.8	5.0	5.9	3.7	-1.4	-4.7	-8.4
	2.7	4.7	7.1	9.9	12.2	13.4	6.1	-6.0	-14.2	-23.7
As Percent of GDP	**5.39**	**5.52**	**5.65**	**5.60**	**5.53**	**5.62**	**5.40**	**5.00**	**4.84**	**4.97**
	0.00	0.00	0.00	0.00	0.01	0.01	0.00	-0.01	-0.01	-0.01
	0.00	0.00	0.01	0.01	0.01	0.02	0.01	-0.01	-0.01	-0.02
	0.01	0.01	0.02	0.03	0.03	0.03	0.01	-0.02	-0.04	-0.05
Federal Debt	**17,627.6**	**18,662.3**	**19,766.4**	**20,898.1**	**22,054.6**	**23,280.1**	**29,702.7**	**37,057.6**	**45,285.6**	**55,213.8**
	0.3	0.9	2.0	3.7	5.9	8.4	20.4	18.1	5.2	-18.0
	0.6	2.1	4.6	8.2	12.9	18.3	41.5	42.0	22.7	-13.1
	2.4	6.7	13.3	22.5	33.9	46.4	91.9	78.3	18.4	-85.3
As Percent of GDP	**78.90**	**80.08**	**81.45**	**82.75**	**83.86**	**85.01**	**88.74**	**90.66**	**91.09**	**91.43**
	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	0.01	-0.01	-0.04
	-0.02	-0.03	-0.03	-0.03	-0.03	-0.02	0.04	0.04	-0.00	-0.06
	-0.06	-0.08	-0.08	-0.07	-0.06	-0.04	0.06	0.01	-0.13	-0.28
State & Local Net Borrowing	**239.0**	**240.5**	**233.7**	**248.7**	**266.0**	**250.9**	**239.5**	**287.2**	**386.1**	**555.0**
	0.9	1.2	1.4	1.7	1.9	2.0	2.0	2.8	4.2	6.4
	2.0	2.5	3.1	3.7	4.1	4.4	4.0	5.4	7.7	11.0
	7.1	8.9	10.9	13.1	14.8	16.1	15.3	20.1	28.4	40.1
As Percent of GDP	**1.07**	**1.03**	**0.96**	**0.98**	**1.01**	**0.92**	**0.72**	**0.70**	**0.78**	**0.92**
	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02
	0.03	0.04	0.04	0.05	0.05	0.06	0.04	0.05	0.06	0.06
State & Local Debt	**3,715.6**	**3,783.0**	**3,836.0**	**3,896.1**	**3,965.4**	**4,011.0**	**4,090.1**	**3,981.6**	**3,969.0**	**4,254.8**
	0.9	2.0	3.3	5.0	6.7	8.6	18.3	30.3	48.0	74.3
	1.8	4.2	7.2	10.6	14.5	18.7	38.2	61.0	93.1	139.1
	6.7	15.2	25.6	38.1	52.2	67.6	141.8	227.4	345.3	512.5
As Percent of GDP	**16.63**	**16.23**	**15.81**	**15.43**	**15.08**	**14.65**	**12.22**	**9.74**	**7.98**	**7.05**
	0.00	0.00	0.01	0.01	0.02	0.02	0.05	0.07	0.09	0.12
	0.00	0.01	0.02	0.03	0.04	0.05	0.10	0.14	0.18	0.23
	0.01	0.04	0.08	0.12	0.16	0.21	0.39	0.54	0.68	0.84
Current Account Balance										
Billions of Dollars	**-589.3**	**-606.3**	**-625.9**	**-646.5**	**-672.0**	**-707.3**	**-893.8**	**-1,214.6**	**-1,665.5**	**-2,319.5**
	-0.4	-0.7	-0.9	-1.1	-1.1	-1.0	3.3	6.7	9.9	13.5
	-0.6	-1.1	-1.2	-1.3	-1.2	-0.6	6.4	13.2	19.4	26.6
	-1.5	-3.4	-3.9	-3.9	-2.7	-0.3	21.9	42.7	62.1	81.5
As Percent of GDP	**-2.64**	**-2.60**	**-2.58**	**-2.56**	**-2.56**	**-2.58**	**-2.67**	**-2.97**	**-3.35**	**-3.84**
	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.01	0.02	0.02	0.02
	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.02	0.03	0.04	0.05
	-0.00	-0.01	-0.01	-0.01	-0.00	0.01	0.07	0.11	0.13	0.14

Baseline levels are shown first in billions of dollars. Results for Scenarios 1-3 are shown next as deviations from baseline, except where noted.
Source: LIFT Modeling Analysis by Inforum.

**Table 13. Real Gross Output by Industry (2020-2045)
Billions (2009$)**

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
GDP (Baseline)	18,357	18,722	19,070	19,437	19,817	20,197	22,193	24,414	26,823	29,416
Scenario 1	2	4	5	6	7	8	8	7	7	8
Scenario 2	4	6	8	10	12	13	15	14	14	15
Scenario 3	12	18	22	26	30	34	39	40	40	40
Farms, Forestry, Fishing	403,892	412,003	419,347	427,154	435,271	443,646	492,117	544,494	599,094	656,185
	10	18	23	30	38	50	102	123	140	166
	15	23	33	51	74	107	314	397	457	524
	34	73	103	157	227	321	1,003	1,320	1,580	1,855
Mining	562,339	572,952	582,073	590,342	597,929	604,866	623,673	631,327	629,833	607,437
	26	37	57	74	98	126	357	587	803	898
	60	63	91	136	179	229	804	1,406	1,797	1,962
	141	185	183	246	388	595	2,423	5,070	6,180	5,504
Utilities	447,546	450,258	452,899	455,754	458,919	461,715	474,706	492,195	513,685	537,785
	36	55	75	96	122	146	141	108	94	85
	62	88	119	154	194	227	274	216	194	176
	169	260	331	412	489	558	711	648	614	584
Construction	965,240	984,753	999,337	1,020,491	1,041,641	1,062,644	1,174,315	1,298,501	1,421,286	1,555,216
	387	678	836	989	1,070	1,103	344	377	331	281
	765	1,245	1,527	1,818	1,955	1,966	659	597	592	529
	2,401	3,875	4,646	5,523	5,824	5,817	1,561	1,551	1,507	1,280
Nondurables Manufacturing	2,935,023	2,977,904	3,019,414	3,070,984	3,124,898	3,178,555	3,478,484	3,824,277	4,214,155	4,640,538
	382	330	476	561	678	772	801	766	811	1,031
	632	560	804	1,046	1,288	1,481	2,114	2,187	2,370	2,713
	1,354	1,792	2,107	2,707	3,253	3,801	5,650	6,138	6,888	8,122
Durables Manufacturing	2,723,280	2,787,990	2,846,968	2,897,080	2,957,062	3,013,421	3,413,155	3,925,744	4,528,844	5,198,155
	530	465	575	671	738	845	878	1,030	1,316	1,769
	846	837	1,070	1,414	1,678	1,838	2,795	3,104	3,512	4,017
	1,807	2,686	2,772	3,685	4,342	4,966	7,463	8,474	9,735	11,130
Wholesale & Retail Trade	2,910,605	2,985,788	3,056,770	3,132,335	3,211,049	3,290,871	3,739,331	4,276,478	4,898,966	5,621,656
	401	536	764	951	1,178	1,384	1,289	1,398	1,781	2,319
	524	790	1,074	1,390	1,751	2,053	2,790	2,923	3,778	4,880
	1,118	2,200	2,875	3,429	4,075	4,694	7,520	8,549	10,649	13,428
Transportation Services	1,052,161	1,079,550	1,104,688	1,132,050	1,159,826	1,188,142	1,351,405	1,547,646	1,779,703	2,051,218
	348	369	472	552	651	734	730	776	888	1,045
	600	670	812	961	1,128	1,258	1,558	1,631	1,868	2,154
	1,772	2,207	2,512	2,869	3,254	3,626	4,777	5,265	6,054	7,001
Water	55,525	56,705	57,826	59,060	60,324	61,611	68,644	77,018	86,603	97,537
	6	8	12	15	19	22	25	34	47	62
	9	14	19	24	30	35	53	73	104	137
	24	44	58	72	86	102	176	249	337	440

Baseline levels are shown first in billions of 2009 dollars. Results for Scenarios 1-3 are shown next as deviations from baseline, except where noted.
Source: LIFT Modeling Analysis by Inforum.

Table 13 cont. Real Gross Output by Industry (2020-2045) Billions (2009$)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Transportation Support Activities (Baseline)	**208,809**	**214,363**	**219,735**	**225,466**	**231,256**	**237,222**	**271,357**	**312,258**	**361,529**	**420,178**
Scenario 1	165	176	200	225	254	279	290	288	303	331
Scenario 2	312	337	375	421	472	515	589	581	616	671
Scenario 3	1,021	1,134	1,235	1,364	1,502	1,634	1,900	1,909	2,009	2,179
Finance, Insurance, and Real Estate	**5,540,311**	**5,670,299**	**5,796,525**	**5,927,820**	**6,062,109**	**6,199,243**	**6,946,023**	**7,795,291**	**8,758,235**	**9,860,849**
	598	840	1,179	1,550	1,976	2,312	2,114	1,980	2,050	2,129
	887	1,241	1,795	2,297	2,909	3,237	3,642	3,192	3,147	3,058
	2,025	3,082	3,974	4,881	5,898	6,744	8,902	8,914	9,080	9,111
Other Services	**10,817,171**	**11,103,251**	**11,391,713**	**11,689,261**	**11,997,455**	**12,311,009**	**13,993,453**	**15,936,040**	**18,178,288**	**20,749,104**
	1,079	1,604	2,241	3,075	4,140	4,961	5,137	4,264	3,646	3,300
	1,703	2,541	3,454	4,667	6,223	7,245	9,209	7,354	6,228	5,236
	4,480	6,969	9,274	11,838	14,467	16,533	20,901	18,361	16,714	15,166
Civilian Government	**2,925,657**	**2,943,653**	**2,963,790**	**2,989,287**	**3,017,707**	**3,046,436**	**3,197,972**	**3,396,129**	**3,618,701**	**3,867,274**
	1,100	1,228	1,403	1,618	1,839	2,039	2,005	1,592	1,349	1,201
	2,173	2,413	2,748	3,146	3,556	3,927	3,984	3,163	2,654	2,293
	7,393	8,212	9,305	10,576	11,849	12,996	13,048	10,509	8,846	7,610

Table 14. Real Exports by Industry (2020-2045) Billions (2009$)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Real Exports (Baseline)	**2,098,214**	**2,163,478**	**2,230,234**	**2,300,898**	**2,371,137**	**2,443,143**	**2,833,468**	**3,284,779**	**3,826,674**	**4,448,582**
Scenario 1	-112	-181	-235	-207	-72	198	3,208	5,741	8,200	10,616
Scenario 2	-162	-241	-260	-134	177	733	6,537	11,922	17,083	21,818
Scenario 3	-296	-420	-243	495	1,780	3,965	22,574	37,378	50,022	61,422
Farms, Forestry, Fishing	**53,160**	**54,326**	**55,530**	**56,930**	**58,417**	**60,024**	**69,199**	**78,415**	**88,029**	**98,504**
	-2	-2	-3	-0	6	17	94	142	189	236
	-4	-4	-2	7	23	48	224	349	476	609
	-9	-8	5	39	100	191	818	1,264	1,725	2,217
Mining	**89,508**	**99,033**	**101,907**	**104,328**	**106,155**	**107,221**	**104,734**	**110,053**	**110,796**	**97,041**
	-23	-52	-78	-100	-113	-115	63	336	597	731
	-24	-53	-77	-92	-91	-64	498	1,325	1,957	1,970
	-27	-52	-51	-2	120	340	2,867	5,416	6,497	5,680
Utilities	**1,478**	**1,482**	**1,485**	**1,489**	**1,493**	**1,497**	**1,517**	**1,535**	**1,554**	**1,573**
	-0	-0	-0	-0	-0	0	1	1	1	2
	-0	-0	-0	-0	0	0	2	3	3	4
	-0	-0	-0	0	1	1	6	9	11	12
Construction	**96**	**97**	**98**	**99**	**100**	**101**	**105**	**109**	**113**	**117**
	-0	-0	-0	-0	-0	0	0	0	0	0
	-0	-0	-0	-0	0	0	0	1	1	1
	-0	-0	-0	0	0	0	1	2	2	3
Nondurables Manufacturing	**413,746**	**422,454**	**432,008**	**442,505**	**452,985**	**463,313**	**513,959**	**566,613**	**619,304**	**670,146**
	-39	-43	-40	-10	53	154	949	1,636	2,473	3,402
	-56	-63	-46	19	141	336	1,975	3,374	4,859	6,438
	-101	-118	-30	249	678	1,366	6,883	10,478	13,545	16,777
Durables Manufacturing	**544,551**	**556,820**	**570,792**	**586,850**	**603,721**	**621,360**	**724,279**	**849,755**	**997,817**	**1,165,765**
	-21	-25	-36	-25	12	74	663	1,126	1,589	2,115
	-45	-50	-41	10	119	288	1,759	3,060	4,480	6,141
	-110	-135	-41	240	698	1,477	6,568	10,952	15,837	21,403
Wholesale & Retail Trade	**163,041**	**167,701**	**171,920**	**176,584**	**181,354**	**186,147**	**211,208**	**241,215**	**274,439**	**308,187**
	-6	-12	-15	-11	0	22	281	581	990	1,564
	-11	-21	-25	-16	9	58	613	1,253	2,102	3,263
	-11	-39	-47	-4	92	266	2,148	3,804	5,974	8,941
Transportation	**120,404**	**124,233**	**128,116**	**131,797**	**135,272**	**138,991**	**159,291**	**182,336**	**211,321**	**245,913**
	-2	-5	-6	-5	-1	7	92	174	270	388
	-4	-8	-10	-7	2	19	195	368	566	804
	-11	-20	-22	-5	30	90	684	1,254	1,898	2,660
Finance, Insurance, and Real Estate	**120,831**	**125,684**	**132,363**	**138,950**	**145,058**	**151,841**	**191,208**	**235,134**	**297,146**	**379,396**
	-5	-10	-14	-15	-10	2	199	319	364	355
	-5	-10	-14	-14	-9	6	241	397	455	447
	-7	-11	-12	-3	18	58	512	785	879	902
Other Services	**368,019**	**383,354**	**400,849**	**419,338**	**437,787**	**456,757**	**565,974**	**691,223**	**860,301**	**1,082,209**
	-17	-38	-54	-56	-39	10	766	1,225	1,366	1,306
	-17	-38	-54	-55	-34	22	919	1,514	1,700	1,643
	-26	-44	-51	-21	53	198	1,913	2,970	3,278	3,317

Baseline levels are shown first in billions of 2009 dollars. Results for Scenarios 1-3 are shown next as deviations from baseline, except where noted. Source: LIFT Modeling Analysis by Inforum.*Source: LIFT Modeling Analysis by Inforum.*

Table 15. Employment by Industry (2020-2045)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Total Employment (Baseline)	**166,003**	**166,658**	**167,511**	**168,385**	**169,375**	**170,404**	**173,798**	**177,499**	**181,105**	**184,607**
Scenario 1	19	29	35	42	49	55	41	31	28	27
Scenario 2	32	48	59	71	83	91	71	50	46	45
Scenario 3	80	109	134	156	174	182	166	137	134	136
Farms, Forestry, Fishing	**2,233**	**2,231**	**2,228**	**2,225**	**2,221**	**2,218**	**2,186**	**2,143**	**2,094**	**2,038**
	-0	-0	-0	-0	0	0	0	0	0	1
	0	0	0	0	0	0	1	1	1	1
	-0	0	-0	-0	0	0	2	3	4	5
Mining	**745**	**746**	**743**	**740**	**736**	**733**	**694**	**652**	**610**	**560**
	0	0	0	0	0	0	0	1	1	1
	0	0	0	0	0	0	1	1	1	1
	0	-0	-0	-0	0	0	2	4	4	4
Utilities	**537**	**530**	**524**	**519**	**513**	**507**	**467**	**434**	**405**	**379**
	-0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
Construction	**9,376**	**9,444**	**9,502**	**9,606**	**9,713**	**9,820**	**10,240**	**10,561**	**10,690**	**10,792**
	2	5	7	8	9	9	3	2	2	2
	5	10	13	15	17	17	4	3	3	3
	8	21	30	36	40	40	6	4	5	4
Nondurables Manufacturing	**5,645**	**5,586**	**5,546**	**5,511**	**5,485**	**5,461**	**5,340**	**5,252**	**5,164**	**5,057**
	0	1	1	1	1	1	1	1	1	1
	1	1	1	1	2	2	2	2	2	2
	1	1	1	2	3	3	4	4	5	6
Durables Manufacturing	**7,129**	**7,052**	**6,987**	**6,910**	**6,844**	**6,782**	**6,455**	**6,221**	**6,015**	**5,786**
	0	1	1	1	1	1	1	1	1	2
	1	1	1	2	2	2	3	3	3	3
	1	1	2	2	3	4	7	8	9	10
Wholesale & Retail Trade	**23,303**	**23,234**	**23,244**	**23,240**	**23,266**	**23,305**	**23,252**	**23,292**	**23,365**	**23,454**
	1	2	3	4	5	6	5	4	4	5
	1	3	4	6	8	9	10	7	7	9
	1	2	5	8	9	10	19	16	19	22
Transportation	**5,981**	**6,009**	**6,061**	**6,110**	**6,167**	**6,229**	**6,468**	**6,743**	**7,053**	**7,382**
	2	2	2	2	1	1	-1	-2	-1	-1
	3	4	3	2	2	1	-3	-4	-4	-3
	8	9	6	3	-1	-5	-14	-14	-13	-11
Water	**69**	**71**	**73**	**74**	**76**	**77**	**82**	**87**	**92**	**98**
	0	-0	-0	-0	-0	-1	-2	-2	-2	-2
	0	-0	-0	-0	-1	-1	-3	-4	-4	-5
	0	-0	-1	-2	-3	-5	-11	-13	-15	-17

Baseline levels are shown first in thousands of jobs. Results for Scenarios 1-3 are shown next as deviations from baseline levels.
Source: LIFT Modeling Analysis by Inforum.

Table 15 cont. Employment by Industry (2020-2045)

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045
Transportation Support Activities (Baseline)	**1,625**	**1,647**	**1,668**	**1,691**	**1,716**	**1,743**	**1,852**	**1,973**	**2,106**	**2,249**
Scenario 1	1	1	1	0	-0	-0	-2	-1	-1	-1
Scenario 2	2	2	1	1	-0	-1	-3	-3	-2	-1
Scenario 3	8	6	3	1	-2	-5	-11	-9	-7	-5
Finance, Insurance, and Real Estate	**9,419**	**9,380**	**9,405**	**9,396**	**9,400**	**9,404**	**9,306**	**9,153**	**9,035**	**8,928**
	0	1	1	1	1	1	2	2	2	2
	0	1	1	2	2	2	2	2	2	2
	1	1	2	2	2	2	4	5	5	5
Other Services	**78,857**	**79,604**	**80,359**	**81,141**	**81,960**	**82,789**	**85,744**	**88,853**	**91,914**	**94,880**
	4	8	10	13	18	21	17	11	9	8
	6	10	13	19	25	29	26	14	11	11
	8	12	18	25	31	35	44	32	33	38
Civilian Government	**22,778**	**22,841**	**22,912**	**22,989**	**23,070**	**23,157**	**23,646**	**24,194**	**24,762**	**25,351**
	9	10	11	12	13	14	13	11	9	8
	16	18	21	24	26	27	27	22	19	16
	54	61	70	79	87	92	90	76	64	54

CONCLUSIONS

In 2020, the state of public infrastructure continues to remain a key domestic policy issue. The expansion of expenditures on waterways, other transportation infrastructure, and utilities generally enjoys strong bipartisan support.

Greater access to sufficient and high-quality infrastructure improves industry performance across the economy and lowers costs for consumers. The MTS provides essential services to businesses, consumers, and governments, presenting an important competitive advantage for American farmers, manufacturers, and other producers. Whether directly or indirectly, every industry depends on MTS infrastructure to transport goods that it buys and, in some cases, that it sells. The MTS facilitates the movement of billions of tons of goods each year. These systems, when linked to rail, roads, and other transportation systems, allow producers to compete in world markets by keeping transportation costs low.

This historical accounting of spending and performance of the U.S. MTS indicates that insufficient efforts to maintain and develop the MTS are leading to a deteriorating state of U.S. public infrastructure. If current patterns and trends continue, the deteriorating condition of our infrastructure systems will significantly undermine our economic competitiveness and prosperity in coming years.

Despite the vital services these systems provide to the U.S. economy, many need long-overdue and substantial maintenance, repair, and modernization. Trends since 2001 have been worrisome, as the volume of investment in the water transportation and water resources infrastructure categories has contracted significantly. Although some recent improvements have been evident, higher funding levels and other substantial changes are needed.

To make up for the long decline in MTS infrastructure spending, a more focused and results-driven effort that expands and sustains higher levels of public and private spending would have positive short- and long-term economic returns. In the short run, investment in infrastructure broadly stimulates aggregate demand that increases economic activity and creates jobs through direct, indirect, and induced demand impacts, but the long-term benefits of infrastructure spending are even more significant and durable. Improvement of the MTS would boost international competitiveness, as updated and well-maintained navigable waterways and ports lower the cost of delivering goods both domestically and internationally by decreasing delays, wasted fuel, and other costs. The lower cost of imports reduces the purchase prices of materials, positively affecting both businesses and consumers through lower production costs and lower prices, while reduced export costs help to boost our trade position in international markets.

Efficiency gains in transportation reduce relative costs across the economy, and so better infrastructure enhances the competitiveness of all industries and the economy as a whole. To the extent that better transportation systems reduce costs for consumers, they also directly enhance standards of living.

This study leveraged available historical data and previous work concerning the economic costs of degraded infrastructure as it considered how an increase in MTS infrastructure spending would affect economic performance. The analysis used the Inforum LIFT model of the U.S. economy to indicate how infrastructure expenditure above current funding levels will help to recover from the long pattern of underinvestment in infrastructure, thus enabling higher growth, improved trade performance, expanded employment opportunities, and enhanced value of household incomes.

The modeling explored more robust funding levels for MTS infrastructure, stretching from 2020 to 2045, that acts to reduce the excess costs of degraded infrastructure. This study modeled three alternative potential efforts to improve MTS infrastructure spending. These alternatives range between $12 billion and $87 billion in additional capital spending over 2020 through 2030, with corresponding increases in maintenance and operations budgets ranging between $37 billion and $255 billion over the same period and higher spending continuing through 2045. Raising infrastructure expenditure by these amounts, using the LIFT model, illustrated how such enhanced spending can generate substantial long-term economic returns that significantly exceed their initial costs. Compared to a baseline forecast that assumed continuation of limited public infrastructure investment that leads to reduced efficiencies and higher costs, the report finds significant short-term and long-term benefits.

In the short term, enhancing the level of infrastructure spending would boost jobs by between 54.7 thousand and 182.5 thousand jobs in 2025, depending on the scenario, though peak gains would subside over time as the productivity effects of better infrastructure take hold. As a result of enhanced efficiency, the economy would realize higher levels of production, income, and consumption. By 2030, the level of real GDP would rise between about $8 billion and $41 billion in 2012 dollars. Over the long term, competitiveness, output, and employment across industries would be enhanced thanks to the productivity-enhancing effects of better infrastructure. Increased productivity largely would be responsible for the higher GDP, but so would higher labor participation within a more dynamic economy. Sustained infrastructure spending creates a progressively more productive economy. Because of cumulative effects through time, by 2045 infrastructure investments could produce economy-wide returns of about $2 to $3 per every $1 spent, after adjusting for inflation. Enhanced economic growth from increased infrastructure investments ultimately would provide greater government revenue levels, which would help to recover the costs of higher public investment spending.

In summary, key results represent expected improvements over the business-as-usual baseline:

- From $8 billion to over $40 billion in additional real GDP by 2030
- By 2030, higher real disposable income, ranging from $11 billion to $50 billion
- Higher real annual income per household, from $79 to $350 by 2030
- Between 55 and more than 180 thousand additional jobs, by 2025
- By 2045, infrastructure investments could produce economy-wide real returns of between $2 and $3 per every $1 spent

As many types of public infrastructure show increasing signs of aging and decay, we are at an appropriate juncture to consider a highly focused infrastructure effort designed to improve safety, increase competitiveness, and improve economic throughput. Accelerated private and public sector efforts to develop MTS infrastructure, including a significant supply of new spending, allows the pursuit of key economic objectives:

1. New funding will help the United States catch up from a well-documented backlog of deferred infrastructure projects that have accumulated, including maintenance, repair, and new capacity. Many of the critical problems already have been identified in prior studies (for example, AECOM 2016 reports 40 key projects).

2. Greater infrastructure investment will help to sustain economic growth and resiliency. By repairing and replacing old and obsolete infrastructure, we reduce the risk of lock gate, dam, and other failures that could cripple regional commodity flows or add substantial transportation costs that leave American industry at a disadvantage. As international markets become increasingly competitive, American farmers, manufacturers, and other producers rely on dependable systems to operate effectively. For relatively little additional expenditure as a share of the GDP,

as is illustrated in this study, the U.S. economy not only can become larger but can become substantially more robust by investing in MTS infrastructure.

Widespread access to high-quality infrastructure thus is indispensable to the United States' economic development and standard of living. A more focused and outcomes-driven infrastructure effort is needed, and new ideas can and should accompany any increase in investment. Strong support exists within the business and manufacturing communities for building a more competitive, nationwide infrastructure network. This report reinforces the value of such action.

GLOSSARY

Capital Investment[1]: The acquisition of goods that are used to produce other goods and services. They are used repeatedly in the production process. Such goods also may be called capital goods or physical capital.

Capital Stock: The supply of goods (structures and equipment) that have been produced and are used repeatedly to produce other goods and services. Capital stocks are the accumulation of past investment activities, minus depreciation of capital due to wear and obsolescence.

Capital Deepening: Increasing the ratio of infrastructure capital per worker, which makes public workers more productive.

Conservation and Development Infrastructure: Examples include non-transportation assets such as irrigation, mine reclamation, fish hatcheries, wetlands, erosion control, and flood-control levees together with transportation-related assets such as non-power dams, locks and lock gates, breakwaters, jetties, sea walls, and non-irrigation related dredging.

Crowding Out: When the economy is close to full employment, additional government spending on infrastructure may have only a small effect on economic growth because of "crowding out". Crowding out means labor and capital resources have to be diverted from the production of private sector goods and services in order to build more roads, transit and water systems, or improve ports and the inland waterway system. It also means that using debt to finance the infrastructure investment will raise interest rates and curtail private investment, because of the high demand for credit in a full employment economy.

Disposable Income: The total income received by households that can be used for consumption and saving. The income remaining after taxes are removed and government benefits, such as social security and unemployment compensation, are added.

Gross Domestic Product (GDP): Nominal GDP is a measure of the dollar market value of all final goods and services produced in an economy in a given year; real GDP is a measure of the quantity of all final goods and services produced. Real GDP is calculated as nominal GDP divided by an index of the GDP price level to remove the effect of inflation. Potential GDP is the maximum sustainable amount of goods and services that the economy can produce, measured in nominal or real terms.

Gross Output: The amount of goods and services produced by an industry. Nominal gross output is a measure of the dollar value of goods and services produced by an industry; real gross output is a measure of the quantity of goods and services produced. Real gross output is calculated as nominal output divided by the average prices of the goods and services produced.

1 Definitions were adapted from the following glossary sources: Federal Reserve Bank of Minneapolis (www.minneapolisfed.org/site-information/glossary), U.S. Department of Commerce, Bureau of Economic Analysis (https://www.bea.gov/help/glossary), Economic Glossary (glossary.econguru.com), The Economist (www.economist.com/economics-a-to-z), econedlink (www.econedlink.org/glossary/) and the U.S. Environmental Protection Agency (www.epa.gov/esam/glossary).

Inflation: A rise in the general or average price level of goods and services produced in an economy. GDP price inflation refers to general price growth for all goods and services in the economy. Inflation also may describe the growth of average prices for particular goods and services.

Infrastructure: The basic capital foundation needed by an economy, composed of buildings and facilities such as roads, bridges and waste disposal systems that support activities such as transportation, communication and energy delivery.

Input-Output (I-O): An accounting framework that shows the relationships between the industries in the economy and all of the commodities that these industries produce and use.

Investment: The acquisition of physical capital goods and infrastructure (e.g., buildings, tools and equipment) used to produce other goods and services. Nominal investment is the dollar value of expenditures for physical capital goods and infrastructure; real investment is a measure of the quantities of acquired physical capital goods. Real investment is calculated as nominal investment divided by the average price for the investment type.

Marine Transportation System[2]: Consists of waterways, ports, and intermodal landside connections that allow various modes of transportation to move people and goods to, from, and on the water.

Operation and Maintenance: The performance of routine, preventive, scheduled and unscheduled actions intended to prevent failure or decline with the goal of increasing efficiency, reliability and safety.

Potential GDP: The maximum sustainable amount of goods and services that the economy can produce. Potential GDP may be measured in nominal (dollar) terms or in real (quantity) terms.

Transportation Support Services: The transportation support component includes all forms of transportation support such as motor vehicle towing services, bus and rail stations, and airports.

Water Transportation Infrastructure: Infrastructure includes waterways, ports, vessels, and navigational systems. These facilitate transportation of passengers and cargo using watercraft, such as ships, barges, and boats, composed of two industry groups: (1) one for deep sea, coastal, and Great Lakes; and (2) one for inland water transportation. This split typically reflects the difference in equipment used.

Water Resources Infrastructure: Includes water containment systems (dams, levees, reservoirs, and watersheds) and freshwater sources (lakes and rivers) that serve transportation, irrigation, flood control, and other purposes.

Water Transportation Services: Transportation services include passenger and freight services for deep sea, coastal and Great Lakes, and inland routes. The U.S. Department of Labor defines Industry Group 449 "Services Incidental to Water Transportation" as "marine cargo handling, towing and tugboat services, marinas, and water transportation services not elsewhere classified."[3]

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2 U.S. Committee on the Marine Transportation System. (2019). Why the Marine Transportation System (MTS) Matters. Retrieved from www.cmts.gov/about/why_mts.

3 United States Department of Labor, Occupational Safety and Health Administration (2019). Retrieved from www.osha.gov/pls/imis/sic_manual.display?id=37&tab=group.

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APPENDIX A: ABOUT INFORUM

Since its founding in 1967, Inforum has been dedicated to improving business planning, government policy analysis, and the general understanding of the economic environment. We work closely with government and private sector organizations to investigate a variety of issues. Inforum services include analytical research and projections of macroeconomic and industrial economic data. We have particular expertise in input-output techniques, global macro and regional economic data, and international market comparisons.

Much of Inforum's work involves the development and use of detailed models of the U.S. economy that combine a "bottom-up" (input-output) structure with a dynamic macroeconomic framework. Because of this approach, Inforum has amassed special expertise in economic analysis at the industrial and capital goods levels. Our flagship model of the U.S. economy is called LIFT (Long-term Interindustry Forecast Tool; additional details are provided in Appendix B). It contains consistent historical data and projections of demand, revenue, production, and international trade for 121 commodities. It includes value added and employment for 71 industries. A second U.S. model, ILIAD, produces forecasts of final demand and output at the 352-commodity level that are consistent with the LIFT projections. Finally, the STEMS model produces forecasts of employment, output, and personal income for the states at a 71-sector level, where these again are consistent with LIFT forecasts.

Inforum has contributed U.S. macroeconomic forecasts to the Blue Chip Economic Indicators consensus forecasts for almost 30 years, and we also contribute forecasts to Consensus Economics and the National Association for Business Economics. Inforum economists often leverage the LIFT model data to develop and maintain economic and industrial forecasts, and this work is extended with "satellite" modeling that connects industry-specific data to developments in consuming or supplying industries and to the macroeconomic environment.

Finally, Inforum regularly completes projects to answer "what if" questions concerning the impact on industries of fluctuation in the macroeconomic environment, such as changes in the exchange rate, or for changes in policies, such as spending on infrastructure. For example, in recent years we have examined the impacts of various fiscal policies on manufacturing output and employment, and we worked to identify the economic impacts of air quality regulations[1].

Inforum researchers explore economic phenomena and principles in a nonpartisan fashion, according to generally accepted economic theory and econometric methods, regardless of the implications for public policy or private strategy. It is known for its proficiency with specific economic data and methodologies, especially for industry-level data, input-output techniques, global data sets, international comparisons, and modeling software. Inforum uses this expertise to build industrial forecasting and "satellite" models to connect data for more detailed sectors to a more aggregated environment.

Inforum offers extensive experience in data compilation, analysis, and forecasting for specific industries and the macro economy. Appendix C contains brief biographical information for key personnel. Additional information is available upon request.

1 A sample of recent reports can be found at www.inforum.umd.edu/organization/news.html.

APPENDIX B: THE LIFT MODEL OF THE U.S. ECONOMY

The Inforum approach to modeling attempts to provide both the dynamics and high-level accounting of macroeconomic models and the industry structure featured in the general equilibrium approach to modeling. The Long-term Interindustry Forecasting Tool (LIFT) is a dynamic general equilibrium representation of the U.S. national economy. It combines an inter-industry input-output (I-O) formulation with extensive use of regression analysis to employ a "bottom-up" approach to macroeconomic modeling. In this way, the model works like the actual economy, building the macroeconomic totals from details of industry activity, rather than by distributing predetermined macroeconomic quantities among industries. For example, aggregate investment, total exports, and employment are not determined directly, but instead they are computed as the sum of their parts: investment by industry, exports by commodity, and employment by industry. LIFT contains full demand and supply accounting for 121 productive sectors.

This bottom-up technique provides several desirable properties for analyzing the economy. First, the model describes how changes in one industry, such as increasing productivity or changing international trade patterns, affect related sectors and the aggregate quantities. Second, parameters in the behavioral equations differ among products, reflecting differences in, for instance, consumer preferences, price elasticities in foreign trade, and industrial structure. Third, the detailed level of disaggregation permits the modeling of prices by industry, allowing one to explore the causes and effects of relative price changes.

Another important feature of the model is the dynamic determination of endogenous variables. LIFT is an annual model, solving year by year, and it incorporates key dynamics that include investment and capital stock formation. For example, investment depends on a distributed lag in the growth of investing industries and international trade depends on a distributed lag of foreign price changes. Moreover, parameter estimates for structural equations largely are based on time-series regressions, thereby reflecting the dynamic behavior of the economic data underlying the model. Therefore, model solutions are not static, but instead they project a time path for the endogenous quantities. The LIFT model thus simulates the economy year-by-year, allowing analysts to examine both the ultimate economic impacts of projected energy or environmental policies and the dynamics of the economy's adjustment process over time.

Despite its industry basis, LIFT is a general equilibrium model, using bottom-up accounting to determine macroeconomic quantities that are consistent with the underlying industry detail. It includes macroeconomic variables that are consistent with the National Income and Product Accounts (NIPA) and other published data. This macroeconomic "superstructure" contains key functions for household savings behavior, interest rates, unemployment rates, taxes, government spending, and current account balances. Like many aggregate macroeconomic models, this structure is configured to make LIFT exhibit "Keynesian" demand-driven behavior over the short run but neoclassical growth characteristics over the longer term. For example, while monetary and fiscal policies and changes in exchange rates can affect the level of output in the short-to-intermediate term, supply forces – available labor, capital, and technology – will determine the level of output in the long term.

The LIFT model thus is particularly suited to examination and assessment of the macroeconomic and industry impacts of the changing composition of consumption, production, foreign trade, and employment as the economy grows through time.

The inter-industry framework underlying the model is composed of five blocks: final demand, supply, factor income, prices, and the accountant. The first block of LIFT uses econometric equations to predict the behavior of real final demand (consumption, investment, imports, exports, and government expenditures). The components are modeled at various levels of detail. For example, aggregate consumption is the sum of 83 consumption products, and aggregate construction investment is the sum of expenditures for 26 types of private structures. Demand by product, with product sectors consistent with the input-output table (*A* matrix), is determined using bridge matrices to convert final demand to the commodity level. Following Wilson (2001), this equation is specified as:

$$f_{121}=B^{C}{}_{121\times 83}c_{83}+B^{E}{}_{121\times 71}e_{71}+B^{S}{}_{121\times 26}s_{26}+g_{121}+v_{121}+x_{121}-m_{121}$$

where *B* represents a bridge matrix for the various components (consumption, equipment investment by purchasing industry, and construction by type[1]) and where remaining variables represent consumption by product, equipment investment by purchasing industry, structures by type, inventory change, exports and imports, and government spending.

In the supply block, these detailed demand predictions then are used in an input-output production identity to calculate real gross output:

$$q = A \times q + f$$

where q and f are vectors of output and final demand by commodity, respectively, each having 121 elements, and where *A* is a 121x121 matrix of input-output coefficients. Input-output coefficients and the bridge matrix coefficients vary over time according to historical trends evident in available data and, in some cases, using assumptions about how technology and tastes might develop in the future.

Commodity prices are determined in a similar fashion. In the factor income block, econometric behavioral equations predict each value-added component (including compensation, profits, interest, rent, and indirect taxes) by industry. Labor compensation depends on industry-specific wages that are determined by industry-specific factors as well as overall labor market conditions. Profit margins are dependent on measures of industry slack (excess supply or demand) and, for tradable sectors, on international prices. Depreciation depends on capital stock levels. Indirect taxes and subsidies are imposed, in most cases, through exogenous ad-valorem rates on overall nominal output.

The industry value added levels are allocated to production commodities using a make matrix. The fundamental input-output price identity then combines value added per unit of output with unit costs of intermediate goods and services to form an indicator of commodity prices:

$$p' = p' \times A + v'$$

where p and v have 121 elements to represent production prices, unit costs, and unit value added, respectively. This identity ensures that income, prices, and output by sector are directly related and are consistent. In turn, relative prices and income flows are included as independent variables in the regression equations for final demand, creating simultaneity between final demand and value added.

As noted above, LIFT also calculates all of the major nominal economic balances for an economy: personal income and expenditure, the government fiscal balance (at both the Federal and S&L government levels), and the current account balance. It also contains a full accounting for population, the labor force, and

1 Note that some details presented here are simplified accounts of the actual model, such as the presentation of the government demand vector. Government spending by commodity type within the model is the constructed as sum of several bridged demand vectors that provide detail for Federal defense, Federal nondefense, and state and local spending. Also, private nonresidential investment includes Intellectual Property, such as spending for software and R&D.

employment. This content is important for building alternative simulations because it ensures consistency between economic growth determined on the product side and the inflation and income components. The model allows us to examine how alternative microeconomic conditions or policies will affect other aspects of the economy. Because the input-output structure allows a bottom-up approach to modeling the macro economy, macroeconomic results fully are consistent with simulated industry disruptions.

Recent projects include analyses of the effects of the sequester and other recent changes to fiscal policy (Werling, Fiscal Shock: America's Economic Crisis, 2012) and analysis of the harm done by policies that allow deterioration of infrastructure (Werling, Failure to Act: The Economic Impact of Current Investment Trends in Airports, Inland Waterways, and Marine Ports Infrastructure, 2012). Long-run economic effects of technological development were assessed in Meade (2010), in the case of vehicle electrification, and in Meade (2009) for the case of policies that encourage technological development to combat climate change. Examples of impact analysis conducted with the LIFT model include a study of the economic effects of port closures following a terroristic attack (reported in Arnold, et al., (2006)) and in two private studies) and the economic impacts of the September 2001 attacks (Werling & Horst, 2009). Other studies of macro and industry impacts of supply constraints include the "Macroeconomic and Industrial Effects of Higher Natural Gas Prices" (Henry & Stokes Jr, 2006) and "Immigration Impacts on the U.S. Economy."[2]

2 Many of these studies, along with other studies and materials, may be found on the Inforum web site: www.inforum.umd.edu. Additional information and resources are available upon request.

APPENDIX C: INFORUM STAFF

Douglas Meade, Ph.D.

Doug is the Executive Director of Inforum and is responsible for business development and strategy as well as being the principal investigator on many projects. He has been with Inforum since May 2006 after serving three years as Deputy Chief of the Industry Division at the Bureau of Economic Analysis (BEA). Before working for BEA, Doug contributed significantly to the development of the LIFT and ILIAD models of the U.S. and the Jidea model for Japan. He has served as principal investigator on a wide variety of projects for private sector and government clients. He has nearly 30 years of experience with economic modeling and data development and has held positions at Data Resources Inc. and the Bureau of Census. Doug received his Ph.D. from the University of Maryland.

Ronald Horst, Ph.D.

Ron is the Director of Research at Inforum. Ron started with Inforum in 2001 as a Research Assistant and joined the full-time staff after receiving his Ph.D. at the University of Maryland in 2006. He directs research activities including model development and application of these models to policy analysis and forecasting. Ron leads production of semiannual macroeconomic-industry forecasts and monthly macroeconomic forecasts. He serves as the principal investigator for projects including analysis of the exhibition industry and provision of specialized industry forecasts. His expertise includes the economics of public infrastructure; freight flow projections; energy economics; projections of detailed industry data; and analysis of terroristic attacks and other economic impacts.

Troy Wittek

Troy is a Senior Economist at Inforum. Troy received his B.A. degree from the University of Maryland in 2007 and a master's degree in Applied Information Technology from Towson University in 2012; he will complete an MBA at the University of Baltimore in 2020. He joined Inforum in 2006 and became a full-time Research Assistant in 2009. Troy's responsibilities include collecting and analyzing statistical data for use in policy analysis, business planning, and academic research. He has helped to write and edit reports for a variety of audiences in the academic, government, and private sectors. He works with the Department of Defense to project defense purchases and skilled labor requirements by industry and by region using Inforum economic models. Other projects include providing detailed short-term forecasts for the banking industry, analyzing the impact of new investment in Asia, and quantifying the economic footprint of domestic industries using IMPLAN.

Trinity Wade

Trinity joined Inforum as a Research Analyst in 2017. She collects and processes economic data, contributes to client presentations and reports, and assists in writing business proposals. She also helps to maintain the Inforum models and to produce forecast materials. Trinity helps to produce quarterly short-term forecasts for the plastics industry, including assembly of historical economic data, projections of key industry indicators, and commentary. She contributes to annual economic analysis of the exhibition industry, joining economic developments to industry performance in attendance, exhibitor participation, and revenues. Additional responsibilities include working with undergraduate interns to test and develop materials for macro and IO modeling courses. Trinity holds a bachelor's degree in Business & Economics from the University of Kentucky.

Douglas Nyhus, Ph.D.

Doug develops and maintains the Inforum international interindustry models and the bilateral trade system linking countries into a world forecasting system. Doug performs many analyses with the international/bilateral trade system. He has supported impact analyses by U.S. government agencies for studies of the Chinese, Korean, Japanese, and Indian economies. He has many years of experience working with international models and data, and he has been instrumental in developing the Inforum international network of researchers. Doug retired from full-time duties in 2013 but continues to work on model development, health care, and other projects. Doug earned his Ph.D. at the University of Maryland.