Failure to Act: Current Investment Trends in our Surface Transportation Infrastructure

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Preface

The American Society of Civil Engineers (ASCE) 2020-2021 Failure to Act studies continue a series of prior studies which began in 2011. As in the previous studies, the purposes of the reports are to provide an objective analysis of the economic implications of continuing "business-as-usual' investment spending on the nation's infrastructure by:

- Estimating the gap between what we are spending now and what we should be spending to bring our systems back to a state of good repair.
- Providing an analysis of the direct economic costs of current investment trends for transportation system users and transportation agency providers; and
- Presenting a macroeconomic analysis of those costs on the nation's households and businesses.

These findings will support ASCE in developing the 2021 *Report Card for America's Infrastructure* and to gauge the adequacy of current levels of investment in that infrastructure. ASCE publishes the *Report Card for America's Infrastructure* every four years and grades the current state of 17 national infrastructure categories on a school grading scale of "A" through "F." This report answers the question "So what?" In terms of economic performance, what does a "D" mean? What does a "B" mean?

The 2020-2021 Failure to Act update is a series of five reports that assess implications for the productivity of industries, national competitiveness, and effects on households given the present trends of infrastructure investment. Together these reports review 11 of the 17 categories addressed by the ASCE Report Card.

This report covers Surface Transportation, encompassing highways, bridges, and transit. Other reports address: water and wastewater delivery and treatment; energy generation, transmission and distribution, airports, marine ports, and inland waterways. When reading this individual report, it is important to bear in mind that the impacts stated in any of these reports do not include compounding impacts from continuing current investment trends on the other infrastructure sectors. However, the final Failure to Act report will summarize the compounding effects for all the preceding reports.

Objectives and Limitations of this Study

The purpose of this study is limited to presenting the economic consequences of continuing investment in America's surface transportation infrastructure on a trends-extended basis. It is not intended to propose or imply prescriptive policy changes. In recent years, many solutions have been proposed to address the declining condition and capacity of America's infrastructure. Solutions put forward have included changing the mix of investment between fixed-rail transit and roadways, expanding "rubber tire" transit (e.g., bus and/or van), implanting variable time tolling policies to limit peak hour highway traffic, technological enhancements such as more widespread introduction of electric vehicles and Connected and Automated Vehicle technologies, leveraging broadband technology to expand telecommuting and reduce commuting traffic, changing land use regulations and thereby generating densities and transit-oriented development, and strategically expanding our highway network. This analysis explains the relationship between the nation's subpar surface transportation infrastructure and its effect on the U.S. economy. Moreover, because our purpose in this study is to address the consequences of current investment trends, this report does not include the potential economic impacts of construction spending that would be required to, at least in part, address identified surface transportation infrastructure deficiencies.

Economics in Pandemics: A Note on COVID-19

The analysis in this report relies on baseline data that predates the COVID-19 pandemic. Data sets and economic models generally lag one to three years behind the present, to allow for data collection, validation, and publication. As a result, economic modeling does not yet account for COVID-19 impacts.

Many transportation planning concepts – from capacity investments to right-sizing strategies for capacity readjustment – rely on future traffic growth forecasts. The COVID-19 pandemic is revealing that travel behaviors and transportation practices can change. For example, the pandemic is demonstrating that telecommuting at much higher rates is possible for significant parts of the workforce, and the future of retailing may swing even more dramatically to e-commerce.

The impacts of these pandemic-related changes on future travel patterns may be significant and sustained. An acceleration of telecommuting and e-commerce adoption may reduce peak period vehicle traffic to key commercial centers while increasing off-peak traffic in other areas. While we cannot be certain whether there will be a net increase or decrease in vehicle miles traveled, time and spatial shifts will be critical factors to consider for future road investment needs.

Another likely trend from COVID-19 is a shift toward relatively more truck traffic, with its own spatial shift as distribution of goods from central warehouses to homes (via light-duty trucks) grows relative to deliveries to retail stores (via medium- and heavy-duty trucks). The speed, magnitude, and breadth of these shifts will need to be monitored and considered in a more dynamic investment planning process. For example, a topic of exploration in the National Cooperative Highway Research Program is right-sizing research.[1] The need for "adaptive" rightsizing will be particularly important as agencies seek to allow for future uncertainty.

Finally, the COVID-19 pandemic is having massive implications for user-based transportation revenue streams, including the gas and diesel excise taxes and transit fares. For example, a recent study released by the American Public Transportation Association (APTA) examines current and forecasted ridership losses, unemployment, state and local tax revenues, epidemiological virus infection patterns, and transit operating costs. The study found that transit agencies are facing an overall funding shortfall of $48.8 billion between mid-2020 and the end of 2021. Even with the infusion of $25 billion provided by the Congress in April 2020 through the CARES Act, transit agencies will still face a shortfall of at least $23.8 billion through the end of 2021.[2]

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1 For example, NCHRP Research Report 917, Right-Sizing Transportation Investments: A Guidebook for Planning and Programming, 2019.

2 American Public Transportation Association, "The Impact of the COVID-19 Pandemic on Public Transit Funding Needs in the U.S., May 2020. https://www.ebp-us.com/en/pdf/generate/node/3302

The pandemic has precipitated massive shifts in transportation demand, supply, and performance, particularly related to the speed and magnitude of trends that were already occurring or expected (such as exacerbating the growth of ecommerce and telecommuting). While it is impossible to say which changes will endure, approaches to planning transportation systems and investments may need significant rethinking, or at the least consider that trends projected from 2019 may be delayed for several years.

1. Introduction

The analysis presented in this report illustrates how different types of surface transportation infrastructure deficiencies affect the U.S. economy and will continue to do so in the future. It highlights not only how deficient surface transportation systems impose costs on households and businesses, but also how these costs relate to the productivity and competitiveness of industries, as well as the prosperity of households.

ASCE issued its first economic report on surface transportation in 2011 and then developed a sketch analysis update in 2016. Changes have been made in our technical approach and assumptions since 2011 due to changes in data and/or modeling availability and, to some extent, to changing circumstances. However, we have preserved much of the previous methodology so that this study is relatively consistent with the prior 2011 study and the subsequent update.

This 2020 analysis of the state of the nation's surface transportation systems represents new analysis, not just an update of previous findings. It considers both the needs for new capacity and the need to maintain and improve the state of repair of existing surface transportation assets. However, the relative importance of new capacity versus current asset preservation and improvement depends on the system in question. The major sections of this report include:

1. The Nation's Urban Public Transportation Systems
    - Economic Cost of Failure to Act
    - Backlog and Funding Gap
2. The Nation's Highway and Bridge Network
    - Economic Cost of Failure to Act
    - Backlog and Funding Gap
3. Total Economic Impacts
    - Direct Economic Costs to Businesses and Households
    - National Economic Impacts
4. Conclusions
5. Appendix – Sources and Methodology

2. The Nation's Urban Public Transportation Systems

Transit is a major component of our nation's surface transportation system. According to the American Public Transit Association (APTA), in 2020:

- About 6,800 organizations provided public transportation through a variety of modes, including an estimated 4,580 nonprofit providers;
- Of the 2,207 systems reporting to the National Transit Database (NTD), 1,279 were in rural areas and 928 were in urbanized areas[3]; and
- Annually, there are about 10 billion annual unlinked transit passenger trips in the U.S., not including intercity trips such as Amtrak or private intercity bus operations.

A significant share of transit capital investment is allocated to new capacity, especially through the U.S. Department of Transportation New Starts transit expansion program. New Starts helps enhance transit access in underserved communities. Some additional support is available through Rail Modernization and Core Capacity spending. The number of rail systems in the U.S. grew as recently as 2017, with the opening of two new operations: the Detroit M-1 Rail streetcar and the Sonoma-Marin Area Rail Transit train. Over the last 20 years, 52 new systems and 124 extensions have opened, resulting in a total of 1,393 additional segment miles. By 2019, this expansion resulted in the nation's transit system comprising over 240,000 route miles. In some locations, new transit capacity is necessary, while other systems report the need to restore service and renew current transit assets.

2.1 Transit Results Overview - The Cost of Extending the Current Trend

This section reports on our direct economic impact estimates of an extended funding scenario. An extended funding scenario assumes current investment trends continue for public transportation. This section of our analysis focuses on the large and growing backlog of capital investment needs in transit.

To understand that backlog, this analysis compiled a national asset inventory using NTD asset data, including data on the useful life and replacement cost of each asset, from which it is possible to estimate the growing backlog of investment needs. All four classes of assets cataloged in the NTD asset data were included in this analysis: service vehicles, revenue vehicles, track, and facilities. APTA's 2019 Public Transportation Vehicle Database, which provides unit costs by vehicle type, was used to complement the cost data provided in the NTD 2018 Urban Area Asset Summary Tool.

Assuming that capital investment for the large and growing state of good repair needs does not increase above current funding levels, the transit sector will face two major consequences: growth in passenger delay resulting from increasing service interruptions (e.g., mechanical failures and secondary service delays on rail systems due to fixed guideway breakdowns), and a significant increase in maintenance and vehicle procurement costs as vehicles become more expensive to maintain and larger fleets are required to compensate for unreliable or faulty vehicles (i.e., to maintain higher spare ratios). To some extent, transit agencies will either add these increased costs to their financial backlogs and shortfalls or agencies will divert funds from desirable new capacity projects. The need will be particularly acute in the near term and possibly over the next several

3 American Public Transit Association, APTA 2020 Public Transportation Fact Book.

years, as transit systems across the country struggle to recover from the impacts of the COVID-19 pandemic on ridership, service, and transit finances.[4]

Presently, transit infrastructure owners are spending a combined annual capital investment of $14.6 billion on maintenance and repair, based on average national transit spending minus estimated investments in transit expansion. While significant, this amount is far below the level of investment needed to maintain a state of good repair on the existing transit system. The Federal Highway Administration's (FHWA) most recent Conditions and Performance Report noted that, as of 2014, the current level of investment in transit asset preservation is insufficient to prevent ongoing growth in the state of good repair backlog.

Table 1 below summarizes the effects of continued underinvestment on the total investment shortfall for the nation's transit systems. The total costs of continuing current levels of underinvestment in our transit infrastructure will total nearly $25 billion over the next 20 years.

Table 1. Annual and 20-Year Cumulative Costs of the Trends-Extended Funding Scenario, Public Transportation

Cost ($Millions, 2019)	Average Annual Cost (2020-2029)	Average Annual Cost (2030-2039)	Cumulative Costs Over 20 years (2020-2039)
Cost to Passengers (direct cost to households)	$118.4	$187.1	$3,054.8
Additional Spare Vehicle Costs (direct cost to transit agencies)	$77.1	$237.6	$3,146.5
Additional Maintenance Costs (direct cost to transit agencies)	$729.3	$1,134.2	$18,635.3
TOTAL, ALL COSTS	**$924.8**	**$1,558.9**	**$24,836.6**

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

Table 2 summarizes each of the three cost types by region and by period. Additional vehicle maintenance expenses from aging transit vehicle fleets represent the largest increase in costs, although passenger delay and additional spare vehicle costs are also substantial over the course of this 20-year analysis. Notably, about a third of the costs are concentrated within the Mid-Atlantic region, undoubtedly reflecting the major presence of legacy transit systems and high transit ridership in the New York/New Jersey/Connecticut metropolitan region.

[4] American Public Transportation Association. *The Impact of the COVID-19 Pandemic on Public Transit Funding Needs in the U.S.* May 2020. https://www.apta.com/wp-content/uploads/APTA-COVID-19-Funding-Impact-2020-05-05.pdf.

Table 2. Trends Extended Funding Scenario, Costs by Type, Period, and Region

Region	2020-2029	2030-2039	Cumulative Total
	Passenger Delay Costs ($M)		
National	$1,183.8	$1,871.0	$3,054.8
Far West	*$326.0*	*$420.1*	$746.1
Great Lakes	*$184.2*	*$233.8*	$418.1
Mid-Atlantic	*$293.3*	*$707.1*	$1,000.5
New England	*$54.3*	*$77.4*	$131.7
Plains	*$45.5*	*$63.6*	$109.1
Rocky Mountain	*$18.8*	*$30.8*	$49.6
Southeast	*$180.2*	*$223.5*	$403.6
Southwest	*$79.2*	*$110.7*	$189.9
Territories	*$2.2*	*$4.0*	$6.2
	Additional Spare Vehicle Costs ($M)		
National	$770.6	$2,375.9	$3,146.5
Far West	$73.5	$219.9	$293.3
Great Lakes	$318.7	$373.9	$692.6
Mid-Atlantic	$245.3	$1,128.4	$1,373.7
New England	$22.0	$213.3	$235.4
Plains	$23.7	$76.1	$99.8
Rocky Mountain	$7.7	$33.7	$41.4
Southeast	$57.6	$146.6	$204.2
Southwest	$19.2	$162.5	$181.8
Territories	$2.8	$21.5	$24.3
	Additional Vehicle Maintenance Costs		
National	$7,292.9	$11,342.5	$18,635.3
Far West	*$1,467.9*	*$2,014.6*	$3,482.5
Great Lakes	*$1,360.6*	*$1,653.9*	$3,014.5
Mid-Atlantic	*$3,180.8*	*$5,592.0*	$8,772.8
New England	*$442.9*	*$676.8*	$1,119.7
Plains	*$105.3*	*$235.8*	$341.1
Rocky Mountain	*$58.5*	*$88.8*	$147.3
Southeast	*$509.0*	*$646.3*	$1,155.2
Southwest	*$131.5*	*$311.0*	$442.5
Territories	*$36.4*	*$123.3*	$159.6

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

The following three tables provider greater detail on the summary costs presented in Table 1 by breaking the costs into several components: transit mode, cost type, and time period (2020-2029 and 2030-2030). Beginning with costs to passengers, Table 3 demonstrates that among transit users, bus riders stand to suffer the most from vehicle delay; this is because motor buses account for, by far, the greatest number of mechanical incidents. Motor busses also account for the highest number of vehicle revenue miles of any mode and a large share of passenger trips nationwide.

Table 3. National cost to passengers (i.e., additional delay to transit passengers) by mode.

Mode	Cost of Passenger Delay ($M), 2020-2029	Cost of Passenger Delay ($M), 2030-2039
Commuter Rail	$21.3	$52.1
Demand Response	$11.9	$16.6
Heavy Rail	$205.1	$318.3
Light Rail	$51.0	$121.4
Motor Bus	$894.5	$1,362.6

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

Assuming transit infrastructure owners continue to spend $14.6 billion each year on the preservation of assets – track, facilities, and vehicles – agencies will need to operate an increasing share of their fleet vehicles beyond their recommended service lives. Aging fleets will, in turn, drive higher operating costs for transit agencies. Table 4 details how this trend translates to increased costs for transit agencies. Specifically, agencies are required to acquire and maintain additional spare vehicles to fill in for vehicles that suffer from incidental mechanical failures. Again, the motor bus fleet – the largest by vehicle count – bears the highest share of these increasing costs of underinvestment in capital. For comparison, FHWA's Conditions and Performance Report estimated, using a different, value-based measure, that the portion of all transit assets exceeding their useful life would increase from 22% to 40% from 2014 to 2030 under a similar "Sustain Spending" scenario.

Table 4. Additional spare fleet costs to transit agencies, national by mode.

Mode	Revenue Vehicles Fleet (2019)	Percent Past Useful Life (2019)	Perc. Past Useful Life (2020-2029)	Perc. Past Useful Life (2030-2039)	Additional Spare Fleet Costs, $M (2020-2029)	Additional Spare Fleet Costs, $M (2030-2039)
Commuter Rail	3,762	25.9%	29.9%	73.5%	$57.6	$684.5
Dem. Response	31,585	10.1%	25.6%	25.8%	$73.3	$75.0
Heavy Rail	5,659	27.2%	35.9%	41.7%	$124.7	$209.8
Light Rail	1,457	29.7%	33.2%	68.0%	$58.0	$652.4
Motor Bus	46,252	17.1%	27.8%	34.6%	$456.9	$754.3

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

Table 5 denotes how an increasing share of fleet vehicles operating past their recommended service lives translates to increased costs to maintain the existing fleet, by mode. Once again, the motor bus fleet bears the highest share of these increasing costs of underinvestment in capital, although maintenance costs will also balloon for the aging rail fleet as well. Note that these costs are estimated by 10-year period.

Table 5. Additional maintenance costs of operating vehicles past their useful lives to transit agencies, national by mode.

Mode	Annual Maintenance Costs, $M (2019)	Additional Maintenance Costs, $M (2020-2029)	Additional Maintenance Costs, $M (2030-2039)
Commuter Rail	$1,600.6	$1,418.6	$3,551.0
Demand Response	$482.3	N/A[5]	N/A
Heavy Rail	$1,623.8	$1,725.4	$2,043.4
Light Rail	$596.6	$585.9	$1,224.2
Motor Bus	$4,330.2	$3,563.0	$4,523.8

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

2.2 The Transit Investment Gap

The measured costs of aging transit assets reported in the tables above may represent only a portion of the true long-term costs of our aging transit infrastructure. As assets that are already past their useful lives continue to age, their frequency of failure will increase, as will the amount of maintenance resources required to maintain these deteriorating transit assets. In addition, over time, a larger share of assets will exceed their useful lives. Finally, as assets age and become more unreliable, experience and research strongly suggest that some transit riders with other travel options will begin to abandon transit systems entirely, resulting in less transit revenue, deferred maintenance across entire systems, and ultimately more service cuts and less travel alternatives – a vicious downward cycle. These impacts are not just felt by transit agencies and riders – fewer transit options mean more driving and roadway congestion across the network. In the largest sense, allowing our nation's transit assets to become increasingly old and obsolete will lead to unpredictable outcomes that are nonetheless likely to entail very sizeable economic losses through 2039, as well as inequitable transportation outcomes across different income and population groups.

Our analysis estimates a current backlog of $176.1 billion for transit investments, considering the vehicles, facilities, and track that are already past their useful lives.[6] If transit capital investment is

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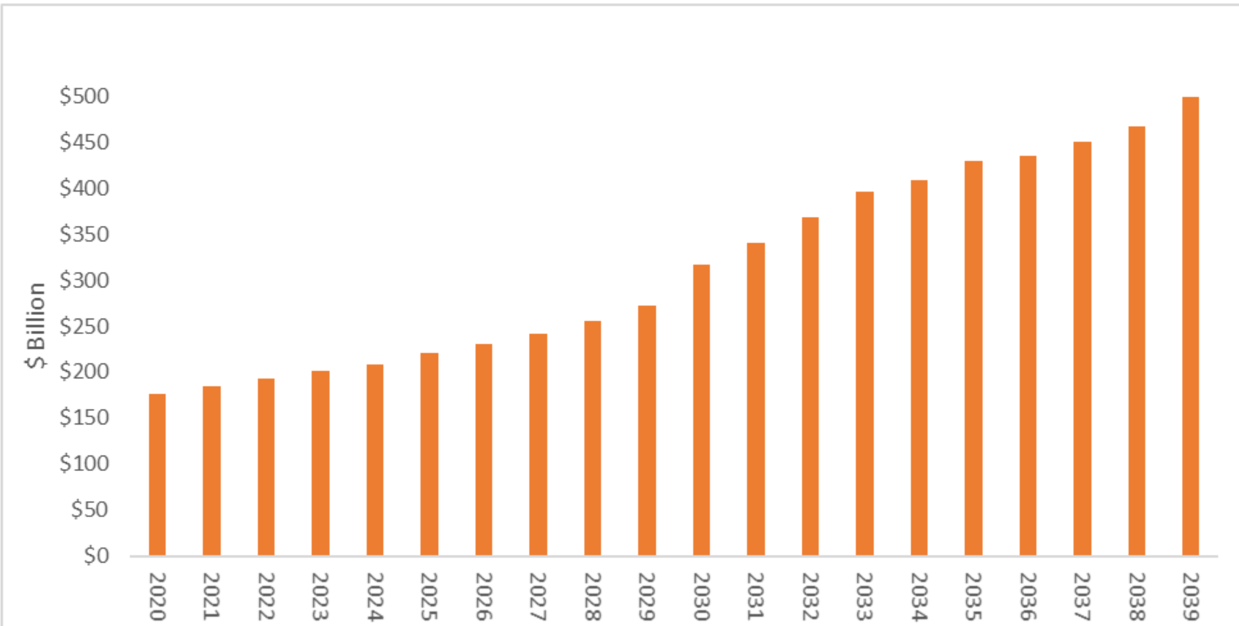
5 In this analysis, we did not make assumptions about the usable life of the vehicles used to replace the current fleet for two reasons. First, the usable life of vehicles is generally expanding, especially for light-duty vehicles. Second, we assume that most vehicles will not be replaced exactly when their usable life is exceeded (hence the growth in backlog). Without information on when replacement vehicles are purchased, we cannot include the cost of replacing a second generation of demand response vehicles. Such costs might occur in the 2030-2039 timeframe, but they might not.

6 For perspective on this backlog cost, FHWA's most recent Conditions and Performance Report (2019) estimated that the replacement value of all the nation's transit assets was $894.8 billion as of 2014, 43% of which was guideway elements. As of 2014, FHWA estimated a national transit backlog of $98 billion, a figure that has grown in just six years.

maintained at the current real level of funding, that backlog value of these asset types is expected to grow to $498.9 billion through 2039 as existing assets continue to age, as shown in Figure 1. In keeping with the FHWA Conditions and Performance Report, we define “state of good repair” as transit capital assets within their useful service life. Our findings show that the current estimated state of good repair backlog is over 10 times greater than the average amount spent on capital investment annually in recent years (i.e., 2012-2018) for all urban transit systems in the U.S. (for both state of good repair and new capacity combined).

Figure 1. Estimated Growth in Transit State of Good Repair Backlog, 2020-2039, Extended



Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

Table 6 provides additional details on the distribution of the backlog by mode, and by 10-year time increments. The backlog balloons during the second 10-year period of this study’s 20-year analysis frame. Delayed impacts of this sort can further exacerbate maintenance deferral, which compounds the problem of backlog growth.

Table 6. Backlog Growth, by Mode and Time Period

Transit Mode	Backlog Growth, 2020-2029, ($2019 Billions)	Backlog Growth, 2030-2039, ($2019 Billions)
Commuter Rail	$13.47	$198.65
Demand Response	$4.69	$0.89
Heavy Rail	$53.95	$70.74
Light Rail	$13.94	$84.97
Motor Bus	$25.57	$32.01
Total	$111.62	$387.26

Sources: National Transit Database 2018 Data Products (Urbanized Area Asset Summary Tool, National Transit Profile Summary, Breakdowns, TS1.1 - Total Funding Time-Series, Annual Operating Expenses Database, Annual Capital Use Database), APTA 2019 Public Transportation Vehicle Database, APTA 2019 Public Transportation Factbook Figure 11. Calculations by EBP.

Identifying funding gaps for new transit capacity is more difficult and requires many more assumptions. To provide some scale of the need, it is useful to consider the status of unfunded New Starts, Small Starts, and Core Capacity transit initiatives (that i.e., projects with approved ratings but without Full Funding Grant Agreements). According to FTA, the unfunded share of approved FY21 projects totals about $30 billion, including $23.6 billion for New Starts, $2.9 billion for Small Starts, and $2.7 billion for Core Capacity.[7] [8] The extent to which state and local financial matching commitments have been confirmed for these projects is uncertain.

The unfunded share reported by FTA does not include any costs for major intercity rail projects, such as the California High Speed Rail (HSR) project or other new HSR initiatives. Further, it includes only about one-third of the total costs of the full Gateway Improvement Project in New York/New Jersey. According to FTA, the federal funding commitments cover only a share of the Hudson Tunnel replacement project and the North Portal Bridge in New Jersey. In addition, the unfunded share does not include funding needs associated with making the nation's transit systems more resilient in the context of both climate change and future public health emergencies. Thus, the estimates in this report should be considered conservative for addressing enhancements to transit capacity needed to address multiple scenarios in underserved or high-demand communities.

3. The Nation's Highway and Bridge Network

Highways

The nation's road network includes more than 4.1 million miles of public roadways. This network carried more than 3.04 trillion vehicle miles traveled (VMT), up from 2.98 trillion VMT in 2004.

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[7] The unfunded share is defined as the difference between the proposed federal share of these projects and their total cost.

[8] Total capital cost, as reported in Table 2A, *FTA Annual Report on Funding Recommendations Fiscal Year 2021, February 2020. https://www.transit.dot.gov/sites/fta.dot.gov/files/2020-07/FY21-Annual-Report-on-Funding-Recommendations.pdf*

Over 1 million miles of Federal-aid highways (24% of total public road mileage) carried 2.572 trillion VMT (85% of total travel) in 2014. Although the 226,767 miles on the National Highway System (NHS) comprise only 5% of total mileage, the NHS carried 1.661 trillion VMT in 2014, about 55% of total travel.[9]

For the most part, the U.S. highway network has not grown significantly over the past two decades. For example, Interstate System center lane mileage has grown by only 2% since 2004, when it consisted of 46,836 miles, compared with 47,944 miles in 2014, the last year for which such data are reported by the FHWA's C&P report. Highway capacity itself, in terms of roadway widenings and the addition of more lanes, has grown only modestly more over roughly the same time; between 2000 and 2018, lane miles of interstates increased by 9%, from 209,000 to 227,000.[10] FHWA data further indicates that total lane miles of interstates *and* arterials combined increased by 12.5% over the same period. This slowdown in capacity growth followed a period of more rapid capacity expansion prior to 2000.[11]

The Federal-aid highway system's pavement conditions have been stable or even modestly improving at recent levels of investment. For example, according to the C&P Report, the share of Federal-aid highway VMT on pavements with "good" ride quality rose from 44% in 2004 to 47% in 2014. Similarly, the share of VMT on NHS pavements with "good" ride quality rose from 52% in 2004 to 59% in 2014. At the same time, the share of VMT on NHS pavements with "poor" ride quality has remained relatively constant at only about 11% since 2014. Importantly, the percent of roadway in poor condition presents an ongoing challenge and additional resources are needed to close that backlog.

Based on the 2019 FHWA Condition & Performance Report, over the next 20 years the funding that will be required to rehabilitate pavement and other operational conditions will average approximately $53 billion annually, or almost $1.1 trillion across 20 years (adjusted to 2019 dollars). Meanwhile, projected spending is estimated at only $41 billion annually. The resulting funding gap is approximately $12 billion annually, or $238 billion over 20 years. In other words, investment must increase 29% over current spending levels to address the current backlog and anticipated future backlogs, after adjusting to 2019 dollars.[12] While not all of the additional spending would be applied to pavement condition per se (it also includes some operational improvements, such as safety improvements and highway design), it represents a reasonable approximation of the spending needed to improve highway state of good repair to a consistently acceptable level. The greatest shortfalls for state of good repair projects are primarily with non-interstate collectors (locally-owned roads) and arterial systems. Note that the $53 billion annual need, and $12 billion gap in meeting these needs do not include system enhancements, system expansions, or bridge spending, which is covered in the next section of the report. The C&P Report estimates are based on the national HERS modeling system.

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9 FHWA Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance Report, 2019.

10 TRIP, "Restoring the Interstate System", July 2020.

11 Transportation to America/Smart Growth America, The Congestion Con, March 2020. That report indicates that lane miles increased by 42 percent between 1993 and 2017, suggesting much greater growth prior to 2000.

12 FHWA C&P Report, 2019. Exhibit 7-7: Improve Conditions and Performance Scenario for Federal-aid Highways: Distribution of Average Annual Investment for 2015 Through 2034 Compared with Actual 2014 Spending by Functional Class and Improvement Type.

Meanwhile, travel time reliability on the nation's highway network is a significant problem, particularly in metropolitan areas with severe bottlenecks. The cost of congestion was monetized for highway users nationwide and found to be almost $180 billion in 2017. The average yearly congestion delay per auto commuter grew by 15% between 2012 and 2017.[13] Over the same five-year period, congestion costs have grown more steeply, increasing 19% for all vehicles, while truck congestion delay costs increased by 35%. Truck delay costs are often passed on to households and businesses.

Few states and metropolitan regions have the resources to greatly expand roadway capacity and build more lane miles. Furthermore, recognition is growing that metropolitan regions cannot "build their way" out of congestion with more lane miles, which can often induce additional traffic and ultimately increase highway congestion. Instead, other strategies, such as improving mass transit options, highway user charges, flexible working hours, telecommuting, and long-term land use changes are increasingly being deployed to manage congestion. The ongoing COVID-19 pandemic is suggesting that the share of the workforce that can work remotely or during off-peak hours is far greater than might have been anticipated pre-pandemic. Looking ahead, reframing trips against travel time reliability metrics – as opposed to congestion – can also improve planning decisions and traveler experiences.

Bridges

The U.S. has approximately 620,000 bridges. Of these bridges, half are owned locally or by other entities, close to half are state owned, and just under 2% are federally owned.

In one respect, bridge conditions generally improved over the last two decades in that the share of all bridges classified as "poor" decreased from 11% in 2004 to 7.6% in 2019. The share of National Highway System (NHS) bridges classified as "poor" also decreased over this period, dropping from 5.6% to 3.7%. However, during the past decade (from 2009 to 2019), the share of bridges classified as "good" also declined slightly, from 48.8% in 2009 to 46% in 2019. Moreover, the number of "fair" bridges outpaced the number of bridges in "good" condition for the first time in 2018.

Bridges face a host of challenges, including climate change and weather vulnerabilities, as well as seismic considerations in some areas. Additional capacity has been and remains needed in selective cases, and a spate of new bridge construction in major U.S. metropolitan areas has addressed some of that need. For example, the New York region has replaced both the Tappan Zee Bridge over the Hudson River in Westchester-Rockland counties and the Brooklyn Queens Expressway's Kosciuszko Bridge in Queens spanning Newtown Creek. In both cases, modern bridges have replaced the former structures and capacity of those bridges have been doubled by twinning the spans. Both replacement bridges now include bicycle lanes and pedestrian paths to help reduce traffic and congestion. Moreover, the new Tappan Zee Bridge (also known as the Mario M. Cuomo Bridge) not only supports bicycling and walking, but also has free parking for people to drive to the bridge and then ride or walk across it. The bridge is also connected to paths on both sides of the river for ease of bike access.

Seismic vulnerabilities have also required new bridge construction and retrofit over the past decade and a half. For example, the Bay Bridge in San Francisco-Oakland, which was severely damaged by the 1989 Loma Prieta earthquake, underwent extensive reconstruction and seismic retrofit over the past two decades, although additional work remains.

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13 Texas Transportation Institute, Urban Mobility Report (published in 2019 with latest data for 2017). This report annually documents roadway congestion and congestion costs in the nation's metropolitan area.

There are selected instances in which additional bridge capacity may still be needed. For example, the I-40 bridge in Oklahoma City, which was built in 1960, is the most traveled bridge in the state with more than 87,000 vehicles daily. However, in general, the much greater need across the entire bridge network is for state of good repair investment, and this is the focus of our cost and funding analysis of bridges.

3.1 Highway & Bridge Results Overview – The Cost of Extending the Current Trend

This section reports economic impact estimates of a trends-extended highway and bridge funding scenario, which we also define as the "failure to act" scenario. For highways, this analysis focuses on metropolitan roadway congestion, deteriorating conditions, and its costs to users. These costs include the monetized value of travel delay for highway users, including costs to industries that rely on highway and bridges to transport goods, and costs to household budgets in gasoline expenditures and vehicle upkeep. For bridges, the costs reflect failing to maintain bridge conditions in an acceptable state of good repair, defined by the percentage of bridges in poor condition.

Congestion Costs

Existing funding levels have not been sufficient to significantly address congestion problems in metropolitan areas, including those due to slowed traffic because of poor roadway maintenance. Congestion related outlays by federal and state governments have had only modest impacts on mitigating the growing burden of roadway congestion.

Our analysis of future congestion and its costs assumes a significant gain in the connected and automated vehicle (CAV) share. It also assumes efficient and effective use of continued current levels of federal spending through the Congestion Mitigation and Air Quality Improvement Program (CMAQ). CMAQ federal investments averaged $2.3 to $2.5 billion from 2016 through 2020. States spend an additional 10% to 20% to meet matching requirements.[14] As noted earlier, the impact of COVID-19 on long term travel behavior may also significantly change travel behavior, but those long-term impacts are presently uncertain and are not reflected in our long-term analysis.

Error! Not a valid bookmark self-reference. below highlights the overall 20-year cumulative results. The cost of delay for all auto users will total more than $3.2 billion. Note that this includes the value of time lost for all travelers, which is not transactional in the economy. At current levels of CMAQ spending and with much greater penetration of CAV technology, the cumulative cost of congestion to businesses and households will still reach about $4.2 trillion by 2039 according to our analysis. This estimate includes a 25% CAV share of the vehicle fleet by 2039, as well as 40% share of electric vehicles of all segments (including, but not limited to CAV), although at this writing it is impossible to accurately forecast the CAV share on U.S. roadways 20 years from now.

[14] Federal Highway Administration, U.S. Department of Transportation, Funding Federal Aid Highways, 2017

Table 7. 20-Year Cumulative Costs Incurred by Businesses and Households of The Trends-Extended Congestion Funding Scenario, by Type, for Highways

Factor	Costs Assuming the Current Pattern of Federal Congestion Outlays ($2019 Billions)
Cost of delay for all auto users	$3,232
Cost of excess gasoline, auto	$159
Direct cost of truck delay	$538
Logistics cost of truck delay (cost of freight)	$234
Cost of excess gasoline, truck	$34
TOTAL	$4,196
U.S. Average Travel Time Index	1.77

Source: EBP calculations based on the Urban Mobility Report of the Texas Transportation Institute, 2017, and CMAQ funding and trends

The $4.2 trillion figure includes the travel delay costs for auto users, excess petroleum-based fuel burned by autos and trucks (including the electricity cost of CAV, in equivalent terms of gasoline), and the direct time costs of truck delay (including operator and other vehicle maintenance expenses). The figure also includes the logistics costs of delay for the freight carried on trucks, a measure of the opportunity cost of late and unreliable delivery of goods to markets or intermediate destinations.

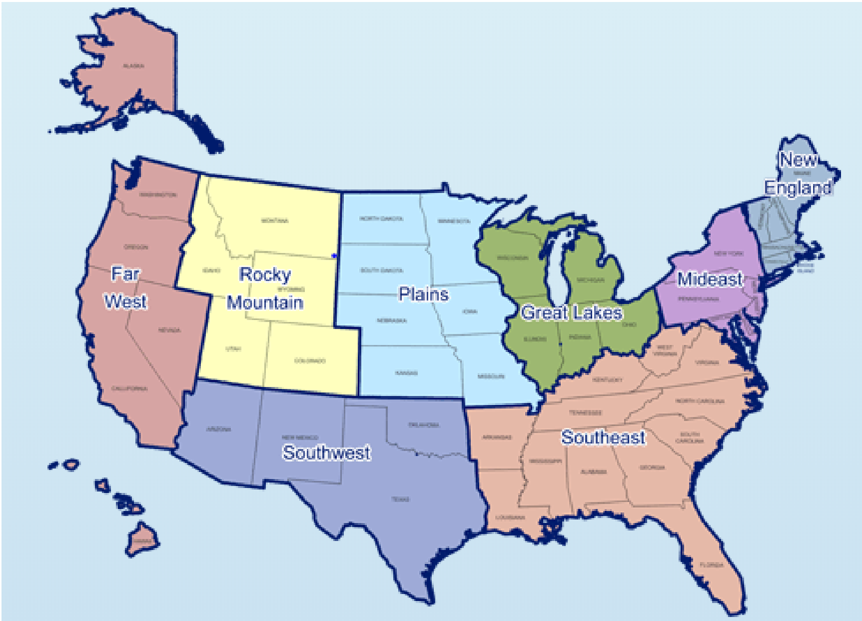
In general, the importance of freight is growing across the United States. In 2018 trucks transported almost 12 billion tons of cargo at an average distance of 174 miles per ton (equaling two trillion ton-miles). By 2040, 15.5 billion tons at an average trip of 195 miles per ton is projected (equaling three trillion truck miles).[15] As just-in-time inventory systems become an increasingly important element of supply chains, these costs will become more critical in maintaining cost-effective productivity across the U.S. economy and competitiveness in global markets.

Based on these assumptions, the levels of congestion that would prevail under this baseline trend scenario would be substantial. Over the 2020-2039 period, the average Travel Time Index (TTI) for the entire 20-year period would be 1.77 for the U.S. In other words, over the next two decades, on average trip times will be 77% higher than what could be expected in free-flow conditions, with additional growth in the outyears.

The national analysis varies by region. The eight multi-state regions defined by the U.S. Bureau of Economic Analysis are used to look at projected sub-national variations, illustrated by Figure 2.

[15] The 2018 baseline and projections are derived from the Freight Analysis Framework Data Tabulation Tool (FAF4), Bureau of Transportation Statistics and Federal Highway Administration, pulled 09/15/2020. Note: these projections predate the COVID-19 pandemic.

Figure 2. Regions defined by the U.S. Bureau of Economic Analysis



Source: U.S. Department of Commerce, Bureau of Economic Analysis

Table 8 includes the total cumulative costs of congestion by region. On average across the U.S., a 60-minute trip in free flow traffic will be expected to take 106 minutes in 2039. In the Far West, the same 60-minute trip on average will take 129 minutes, and in the Plains – the region with the lowest level of congestion – the trip would require 83 minutes on average.

Table 8. 20-Year Cumulative Costs and 20 Year Averages Travel Time Index, by Region

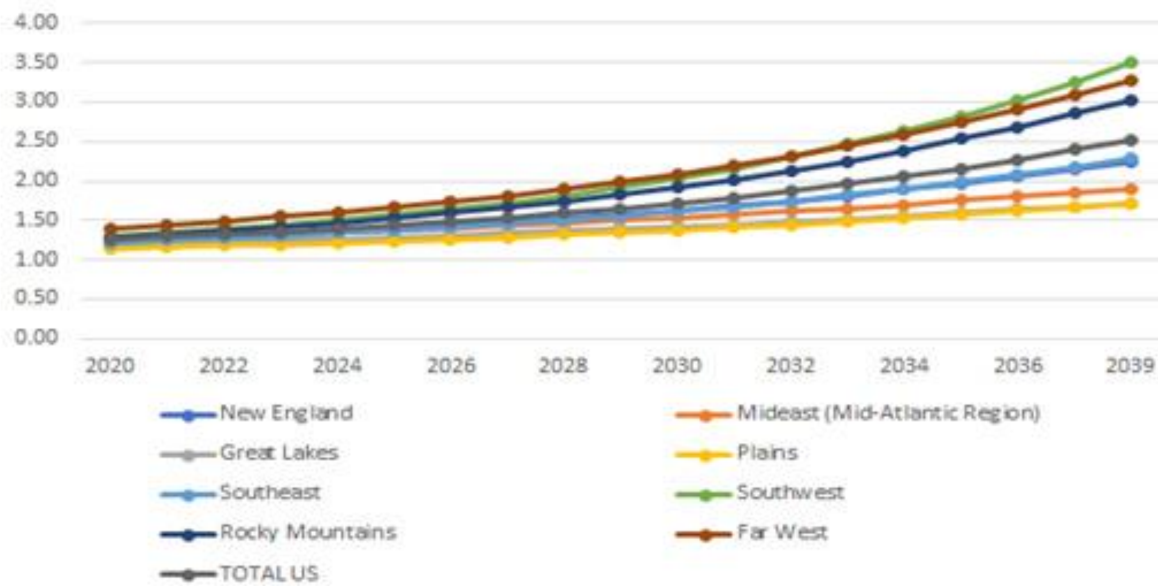
Region	Congestion Costs ($2019 Billions)	Travel Time Index
New England	$170.8	1.65
Mid-Atlantic	$620.8	1.54
Great Lakes	$335.7	1.42
Plains	$120.3	1.38
Southeast	$684.8	1.65
Southwest	$800.7	2.14
Rocky Mountains	$135.3	1.98
Far West	$1,327.6	2.16
Total Congestion Cost	$4,196.2	1.77

Source: EBP calculations based on the Urban Mobility Report of the Texas Transportation Institute, 2017

The Far West and Southwest regions are projected to have the highest cumulative dollar cost of congestion as well as the highest rates of congestion, roughly 21% to 22% higher than the national average. The high congestion levels and costs in these two western regions are the result of growing populations, higher VMT growth, and cities with larger footprints and less public transportation.

Figure 3 provides additional detail regarding projected levels of congestion by region over the entire 20-year analysis time frame. By 2039, all regions experience major increases, with three regions – the Far West, the Southwest, and Rocky Mountains – reaching TTI levels at or above 3.0. Whether such high levels of congestion would ever be reached is of course unknown, as other behavioral changes might set in to reduce those levels, as well as proactive operational strategies to optimize the use of existing roadways. However, these results reflect the economic costs of unconstrained growth in vehicle miles traveled.

Figure 3. Growth in the TTI, Trends-Extended Scenario, by Region



Source: EBP calculations based on the Urban Mobility Report of the Texas Transportation Institute, 2017

With the effects of both COVID-19 and technology, the future effects of CAV are murky. It is possible that in a post-COVID pandemic world, land use patterns in metro areas will become much more dispersed and suburbanized, as people choose to maximize personal indoor and outdoor space. If this shift is a long-term phenomenon, traffic and VMT growth could be even worse than currently projected. Moreover, although a lot of prevailing scholarship indicates that CAV development will increase roadway capacity, some predictions note a potential for increases in auto commuting.[16] As CAV adoption increases, it in fact may lead to more driving if it creates more effective capacity – the same causality problem that is associated with increasing physical highway capacity.[17] Effective capacity implies that less spacing is needed between operating vehicles to safely navigate roadways in computer operated automated vehicles, which implies that more vehicles can use existing roadways. Research has shown

16 For example, see Ghiasi, et. al., A mixed traffic capacity analysis and lane management model for connected automated vehicles: A Markov chain method; Transportation Research Part B journal homepage: www.elsevier.com/locate/trb; October 31, 2017.

17 Streetsblog New York City, "The Coming Carmageddon: Will Our Leaders Solve NYC's Transportation Problem?" May 15, 2020.

however, that in the long run, even when controlling for other demand factors, building more lane miles induces more driving.[18] As with building new highway lanes, it is possible that over time CAV capacity gains will be offset to some extent by increased driving.

Bridges' State of Good Repair

In conjunction with the roadway capital analysis, this report employs the 2019 C&P report and the FHWA's National Bridge Inventory Analysis System (NBIAS) model. According to the C&P report, $24.7 billion annually over 20 years is required to upgrade the U.S. bridge system to a state of good repair. However, annual investments are anticipated at $15.7 billion (in 2019 value), which is the annual "steady state" level of bridge investment seen historically over recent years.[19] Thus, the anticipated investment gap to bring the U.S. bridge system to a state of good repair is $9 billion per year, or $181 billion over 20 years.

The NBIAS model includes the extensive National Bridge Inventory database of 620,000 bridges. However, the NBIAS model includes a screening tool for economic analysis that emphasizes 456,000 bridges that will have a greater direct economic return on investment than the projected cost of upgrade. Based on the NBIAS model, the current annual investment of $14.4 billion in 2014 dollars ($15.7 billion in 2019 value) appears adequate to address the bridges for which the economic benefits from upgrades will exceed the cost of investment. However, bridges that service school bus routes, provide access to hospitals for rural residents, preserve bridges of historical significance, or save personal travel time for travelers are valuable to the quality of life of our communities. Thus, this analysis is conservative in estimating true repair costs.

3.2 The Highway and Bridge Investment Gap

To estimate the highway investment gap, our analysis considers an alternative increased investment scenario. While numerous increased investment scenarios could be hypothesized, our approach has been to select one that deals with declining time travel reliability and deferred state of good repair projects in a relatively regular and systematic way. This scenario does not assume that all congestion would be relieved, as universal free-flow travel is not realistic.[20]

The 20-year cumulative investment gap between what we are currently spending and what we need to spend to decrease congestion and maintain our assets in a state of good repair is approximately $1.5 trillion in 2019 dollars. This gap is detailed in Table 9. The figure is

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19 The $22.7 B in need to upgrade the bridge system and the $14.4 B figure for baseline annual bridge spending comes from the 2019 *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* put together by FHWA and FTA, Exhibits 7.6 and 7.4, respectively. These dollars are in constant 2014 dollar values and reflect , both federal and state spending.

20 It should be noted that such an increased investment scenario at levels commensurate with the estimated gap would generate very desirable social dividends in terms of its benefits greatly exceeding the investment cost. The enhanced investment scenario results in significant cost savings, primarily in commuter time savings, and is economically feasible with present value of savings in congestion around 1.1 trillion dollars (in fixed 2019 prices, discounted at 7%), whereas the investment cost and associated maintenance costs (also discounted at 7%, in fixed 2019 prices) is about 0.8 trillion dollars. Therefore, the Net Present Value of the investment is about 0.3 trillion dollars, with an Internal Rate of Return of approximately 13%.

comprised of capital investment, cumulative incremental maintenance costs associated with these capital investments, and the costs to bring federallyfunded roadways to a state of good repair. The gap reflects the significantly higher costs of highway construction in congested metropolitan areas as well as additional infrastructure costs to accommodate the assumed rate of CAV use.

Table 9. Estimated Highway Investment Gap, Including CAV Penetration (billions)

	2020-2029	2030-2039	2020-2039
Estimated Federal and State Funding	$644.0	$807.8	$1,451.7
Needs to Achieve a Congestion Level of 1.2 and a State of Good Repair	$1,510.1	$1,478.3	$2,988.3
% budgeted	43%	55%	49%
Investment Gap (Budget Shortfall)	$866.1	$670.5	$1,536.6

The estimated Federal-Aid Highway Budget shown does not include Administration, Transportation Research and miscellaneous other programs. The highway expenses show reflect about 96% of the total budget.
Sources: U.S. Department of Transportation, Federal Highway Administration, Funding Federal Aid Highways, January 2017. Calculations by EBP.

The capital gap is expected to narrow slightly in the 2030-2039 period from the preceding decade, primarily because the penetration of connected vehicle/autonomous vehicle technologies (CV/AV) promises to create more efficient use of infrastructure capacity by 2039. Though this analysis incorporates a 25% CV/AV share of the vehicle fleet by 2039 as well as 40% share of electric vehicles of all segments (including, but not limited to CV/AV), disagreements exist over the extent of CAV penetration, its timing, as well as its effects, as previously noted.

What is the Bridge "Investment Gap?"

The investment gap is summarized in Table 10, below. As noted above, the gap is based on upgrading the nation's bridges to the state of good repair to negate the economic costs associated with diversions due to detours past unusable bridges and/or traffic congestion if one or more lanes are shutdown or otherwise restricted. Other considerations include safety factors and quality of life of isolated or otherwise small user communities. The investment gap is based on bringing all bridges to a state of good repair (SOGR) for safety and equity, as well as economic return. The economic analysis in Section 4, however, is limited to bridges that will have a greater economic return than investment cost.

To estimate the bridge gap, our analysis is based on the 2019 C&P report, including:

- $22.7 billion annually over 20 years to upgrade all bridges to SOGR (Exhibit 7.6).
- Current spending levels of $14.4 billion annually (Exhibit 7.4)

Both required costs and annual spending are reported in constant 2014 dollars. A GDP deflater from the U.S. Bureau of Economic Analysis was applied to bring projected investment needs to $24.7 billion annually and anticipated investments to $15.7 billion.

Table 10. Estimated Bridge Investment Gap (2019 billions)

	2020-2029	2030-2039	2020-2039
Projected Investment Level on a Trends Extended Basis	$156.8	$156.8	$313.5
Estimated Need	$247.1	$247.1	$494.2
% of Need Anticipated by Extended Trends	63%	63%	63%
Investment Gap (Budget Shortfall)	$90.4	$90.4	$180.7

Sources: U.S. Department of Transportation, Federal Highway Administration and Federal Transit Administration, Status of the Nation's Highways, Bridges and Transit: Conditions and Performance, 23rd Edition, 2019. Calculations by EBP.

Using a trends-extended scenario, total anticipated capital investment for bridges and highways is anticipated to address 54% of needs over 20 years, as summarized below:

- Total Needs - $3.24 trillion
- Total Investment anticipated: 1.77 trillion
- Total Gap: $1.48 trillion:

4. Total Investment Gap for Surface Transportation Systems

In total, about $5.4 trillion will be needed from 2020 through 2039 to address condition and capacity issues forecast for the multiple components of surface transportation across the U.S. (Table 11). During this timeframe, spending of almost $2.9 trillion is projected, or about 54 cents on the dollar, which leaves an overall investment gap of more almost $2.5 trillion.[21] In the 2011 Failure to Act study reported a gap of almost $3.7 trillion over a 30-year time frame with total funding projected at 49 cents on the dollar. This is an indication that spending is nearly flat, and little progress has been made over the past 10 years to close the surface transportation investment gap.

TABLE 11. Projected Surface Transportation Infrastructure Gap, 2020-2039 ($2019)

Surface Transportation Component	Projected Needs	Projected Investment	Estimated Investment Gap
Highways (congestion & pavement management)	$4,055	$2,281	$1,774
Bridges	$494	$314	$181
Transit & Intercity Rail	$842	$308	$535
Totals	$5,392	$2,902	$2,490

Columns and rows may not add due to rounding.

5. Economic Impacts

The preceding analysis has summarized the gap between what investment is expected annually for surface transportation infrastructure and what will be needed to assure a reliable transportation network for people and freight. This section explains the economic consequences of growing congestion, a stagnant repair backlog on our highways, bridges in poor condition, and transit that does not meet a state of good repair.

Costs incurred by both households and businesses can include, but are not limited to: 1) lost worker productivity due to longer commuting times and driving times while workers are on the clock; 2) increased supply chain costs as longer and more circuitous truck trips add truck operation and logistics expenses; 3) increased vehicle operating and maintenance costs for trucks, buses, and private auto users; 4) increased expenditures for idling and petroleum based motor fuels and 5) increased costs to transportation agencies (e.g., for more vehicle or bridge maintenance), which are passed on to taxpayers and transportation system users.

These increased costs will make U.S. products and services more expensive and less competitive or affordable. Consequently, business income will fall, and wages and employment will be reduced. At the same time, household will bear the additional expenses of poor infrastructure in the form of higher vehicle operational costs and further reduced purchasing power for other consumer goods and services. Combined, these business and household effects will contribute to a downward spiral as wages decrease and sales shrink, leading to further declines in business income and further cuts in worker income.

21 The gap over 30 years calculated for the 2011 version was $3.6 trillion in 2010 value, which is roughly $120 billion per year compared to $110 billion annually in this study. The primary reason is that this study was more constrained on building lane miles.

5.1 Direct Economic Impacts to Businesses and Households

Should investment in our nation's highways, bridges, and public transportation systems continue at current trend levels of capital spending, households and businesses will incur nearly $2 trillion dollars in extra costs cumulatively over the 20-year timeframe of this study. These costs do not include all the travel delay incurred by private auto users under congested conditions, although they do include "on-the-clock" travel. As shown in Table 12, costs break down to almost $1.8 trillion to industries and more than $217 billion directly to households. The direct costs to households equate to more than $1,500 per household over 20 years. Moreover, if industry costs are passed onto consumers, the cumulative cost per household could be as high as $12,500 over 20 years, or $625 annually. The effects will compound greatly over time; losses to households and industries will amount to $677 billion over the 2020-2029 period and $1.3 trillion during the 2030-2039 decade.

Table 12. Direct costs to industries and household from deficient surface transportation infrastructure ($ billion)

	2020-2029	2030-2039	2020-2039
Industries	$594	$1,158	$1,752
Households	$83	$134	$217
Totals	$677	$1,292	$1,969

Source: EBP analysis

Costs to industries will vary widely. Costs accruing to all industries in the U.S. will be $155 billion in the year 2039. Roughly 43% of these costs, $66 billion, will be shouldered by four logistics sectors: trucking, wholesaling, warehousing and transportation support services, and these costs will be passed to industries in addition to the direct costs to manufacturing, agriculture and extraction industries. The 15 sectors most impacted by a failure to maintain an efficient surface transportation system are projected to account for about 85% of total industry costs in the year 2039. The spread of costs by sector is illustrated in Table 13, below.

A decaying surface transportation system will affect costs in every U.S economic sector that depends on business travel and freight shipments. Sectors, including manufacturing and healthcare, will fall behind international competitors as transportation costs borne by U.S. industries drive prices higher, because: (1) moving products by truck to airports, seaports, and to domestic customers, will be more expensive; and (2) transportation costs will lead to price increases for incoming materials and needed onsite professional services that are required for production. Moreover, reduction in household disposable income will reduce the scale of domestic markets for non-essential purchases, further affecting business sales of U.S. technology sectors.

Table 13. Cost to Industry in 2039 from Deficient Surface Transportation Infrastructure

Industry Sector	Projected Direct Cost Impacts in 2039	Percent of Impacts
Truck transportation	$40.0	26%
Wholesale trade	$19.3	12%
Retail	$13.9	9%
Manufacturing	$12.4	8%
Construction	$8.2	5%
State and local general government	$5.5	4%
Health Care Services	$5.3	3%
Administrative and support services	$4.7	3%
Miscellaneous professional, scientific, and technical services	$4.3	3%
Warehousing and storage	$3.5	2%
Other transportation and support activities	$3.4	2%
Other services, except government	$3.4	2%
Food services and drinking places	$3.3	2%
Waste management and remediation services	$3.1	2%
Agriculture	$2.2	1%
Other	$22.9	15%

5.2 Impacts to the U.S. Economy

The $2 trillion in direct economic costs to households and industries detailed in the preceding section provided the inputs to the LIFT national macroeconomic model. The LIFT model captures the dynamic impacts that result as the direct costs to industries and households recycle through the economy and affect demand, supply, and price levels. Overall economic impacts of deficient surface transportation infrastructure are summarized in Table 14.

Table 14. Losses to U.S. Economy due to Failing Transportation Infrastructure ($2019 billions)

Year	Business Sales (Output)[22]	GDP	Disposable Income	Jobs
Losses in the Year 2029	$216	$97	$71	378,000
Losses in the Year 2039	$824	$371	$227	726,000
Cumulative Losses 2020-2029	$1,035	$472	$334	N/A
Cumulative Losses 2030-2039	$5,186	$2,341	$1,504	N/A
Cumulative Losses 2020-2039	$6,221	$2,813	$1,838	N/A

Columns may not add due to rounding. Note: Losses and increases reflect impacts in a given year against national baseline projections. These measures do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

In total, $472 billion in GDP is expected to be lost from the U.S. economy from 2020 to 2029, while an additional $2.3 trillion is expected to be lost in the following decade. This is a larger impact on U.S. GDP than anticipated in the 30 years forecasted in the 2011 study. The good news is there is time to address the identified impacts because 80% of losses are anticipated to be experienced from 2030 through 2039.

As shown previously in Table 14, direct losses imposed on businesses and households will accumulate over time. Moreover, as time goes on, disadvantages will compound. Economic slowdowns will be observed over the 2020-2029 period due to mounting surface transportation congestion and unmet needs in maintaining transit systems and addressing state of good repair for bridges. However, impact will worsen from 2030 to 2039 if these needs are not addressed.

Our economy hinges on being able to transport goods economically, swiftly, and safely across the country from buyers to sellers and to and from airports and seaports for international commerce. Similarly, our economy relies on the efficient and reliable movement of people, offering multiple modes for travel wherever possible. Our findings indicate that if the needs identified for 2020-2029 are not addressed and our surface transportation systems do not become more modern, reliable, and resilient, business productivity will weaken, and wages and household income will fall. Consequently, domestic goods are expected to become more expensive to produce and U.S consumers will have less purchasing power. These two factors will create a downward economic spiral that will intensify over time.

5.3 Total Economic Output and GDP

Economic Output Drops Precipitously

Total output represents total economic activity in producing and providing goods and services in the U.S. economy.[23] Without changes in investment strategies to modernize our surface

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23 According the U.S. Bureau of Economic Analysis, gross output consists of both the value of what is produced and then used by others in their production processes and the value of what is produced and sold to final users. Industry "value added" is the value of industry sales to other industries and to consumers minus the value of its purchases from other industries. Value added is a nonduplicative measure of production that when aggregated across all industries equals gross domestic product (GDP) for the economy.

transportation infrastructure, business sectors across the nation are expected lose more than $6 trillion from what would be supported with a balanced and moderately congested transportation system. Moreover, our findings indicate that negative impacts will build slowly from 2020 but accelerate in the second decade in this analysis. This might be explained 1) as the escalation of cumulative effects, such as lower physical and human capital accumulation over the first 10 years that leave smaller capital stocks and less productive capacity in the later years, even as excess costs continue to rise due to exceedingly poorer roadway and transit conditions, and 2) higher excess costs simply become more problematic and harder to avoid. For example, a few bad roads might be bypassed with little additional cost, but many bad roads require greater additional costs.

Table 15 shows the total output losses by industry sector due to underinvestment in transportation infrastructure from 2020 to 2029 and 2030 to 2039. Manufacturing, finance, insurance and real estate, and professional services are projected to account for 57% of all losses through 2039. Note, the 15 sectors shown in Table 15 and in subsequent industry tables are consolidated from 64 industries within the LIFT model.[24]

Table 15. Aggregated Output Losses by Industry Sector ($2019 billions)

Sector	2020-2029	2030-2039	2020-2039
Manufacturing	$324	$1,508	$1,833
Health Care	$51	$363	$415
Professional Services	$110	$625	$734
Other Services	$94	$436	$531
Logistics	$64	$320	$384
Finance, Insurance and Real Estate	$170	$847	$1,017
Construction	$29	$124	$153
Retail trade	$34	$164	$198
Accommodation, Food and Drinking Places	$25	$120	$145
Transportation Services (excluding truck transportation)	$24	$114	$137
Mining, Utilities, Agriculture	$33	$152	$185
Information	$54	$309	$363
Educational Services	$8	$32	$40
Entertainment	$10	$47	$57
Social Assistance	$5	$25	$30
Totals	$1,035	$5,186	$6,221

Columns and rows may not add due to rounding.
Note: Losses and increases reflect impacts in a given year against national baseline projections. These measures do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

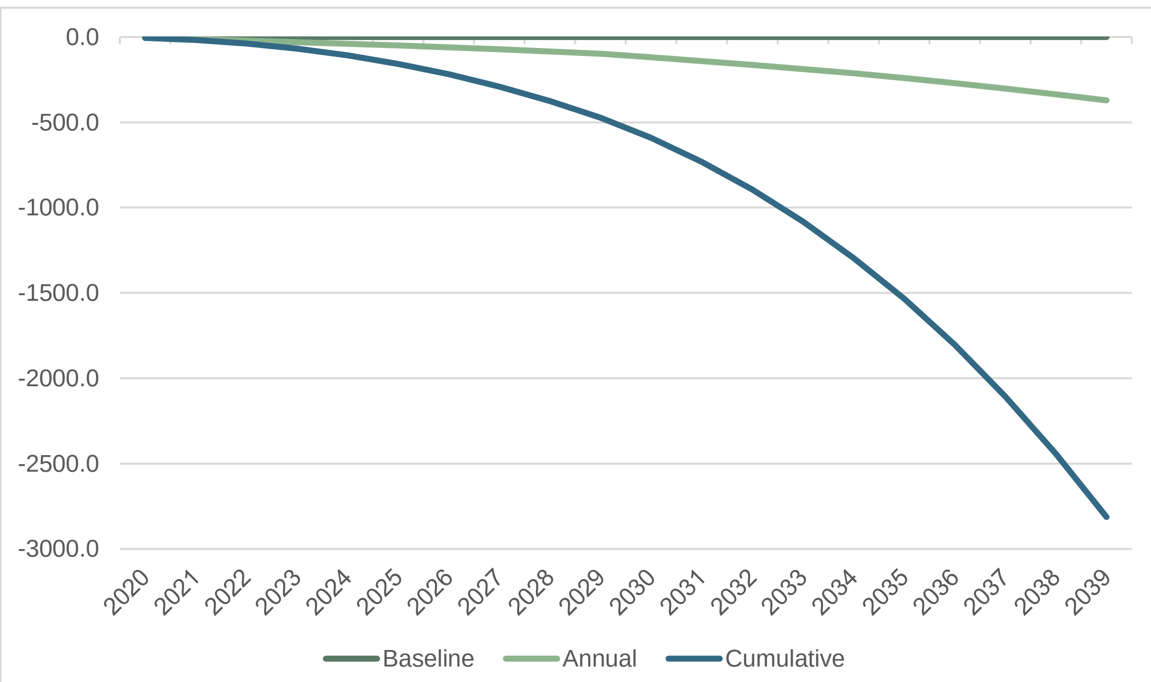
24 The full concordance table of the industries shown to the full list of 64 are shown in the appendix.

Gross Domestic Product Falls

Failing to address state of good repair, congestion, and travel reliability issues is expected to cost the national economy more than $2.8 trillion of GDP over the next two decades. The cumulative economic effects from substandard roads and transit systems will escalate over time. Costs of production and product delivery will increase as more dollars are needed for transportation services. As a consequence, prices will rise, and profit margins and sales will be curtailed as the excess transportation costs are either absorbed by businesses to retain market share or passed on the customers. These effects will result in businesses losing income and profits and production capacity falling, leading to increased imports and decreased exports. Additionally, worker income will decline, leaving less purchasing power among households.

Each of these dynamics will become worse from one year to the next. Given the impacts of surface transportation infrastructure that does not meet a state of good repair/minimum tolerable standards, lost GDP is expected to be $5 billion in 2020, $97 billion in 2029 and $371 billion in 2039. Figure illustrates the relationship of annual and cumulative losses of GDP from the national economy.

Figure 2. U.S. GDP Impacts 2020-2039 from the Gap in Surface Transportation Infrastructure Investment (billion 2019$)



Note: Losses reflect impacts in a given year against national baseline projections (shown as 0). These measures do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

5.4 Disposable Income: Purchasing Power

Over the 20-year timespan of this analysis, U.S. households will lose an aggegate total of $1.8 trillion of disposable income in 2019 value. Each household in the U.S. stands to lose an average of almost $13,000 in disposable income aggregated accoss the 20 years. From 2020-2029, the average loss of disposable income is expected to be $2,400 per household ($240 per year) Over the next 10 years, 2030-2039, disposable income per household is expected to decrease by an additional $10,200, or more than $1,000 per year. This change in income tracks the investment gap which will grow over time if not addressed, and will progressively add to business and household costs.

Disposable income is what is used by households to purchase goods and services. Income reduction will lead to less consumption and/or purchases of cheaper goods. Lower levels of consumer purchases or substitution of less expensive goods will reduce demand and therefore lower industry output and GDP. As income falls over time, fewer goods and services willl be purchased (or more purchases will be delayed), leading to even further drops in industry demand. The declining levels of household disposble income over time is shown in Table 16.

Table 16. Losses in Household Disposable Income Over Time

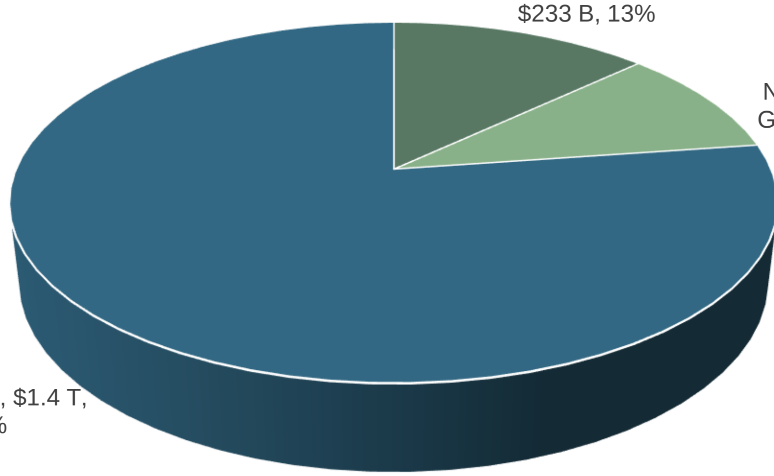
	Total ($2019 billions)	Per Household ($2019)
Annual		
2029	$71	$503
2039	$227	$1,514
Cumulative		
2020-2029	$334	$243
2030-2039	$1,504	$10,302
2020-2039	$1,838	$13,050

Notes: cumulative losses per husehold represent the total doisposable income losses in each period presented divided by the average number of U.S. households projected for the years shown. Losses and increases reflect impacts in a given year against national baseline projections. These measures do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

The lost income will lead to about a $1.8 trillion decline in personal consumption across U.S. industries by 2039, which averages more than $5,000 per capita. As displayed in Figure 1, about 23% of these foregone purchases will be in durable and non-durable goods and about 77% will be services.

Consumption of gasoline and other fuels are projected to increase by about $70 billion dollars over 20 years, without factoring in future technology changes. Extra consumption of gasoline might be the result of detours imposed by bridges in poor condition, bypassing roads in poor condition, and idling on increasingly congested highways. Sectors that will lose the personal consumption expenditures include health care, housing, financial services and food service, and accommodations – including restaurants and hotels. These are industries that support the quality of life of U.S. citizens, and are expected to lose business sales associated with discretionary expenditures as individuals and households reprioritize spending to adapt to declining income. Table 17 lists selected industries by the cumulative changes in consumption expenditures expected from 2020-2039.

Figure 1. Decline in Personal Consumption, 2020-2039.



Notes: Cumulative declines in personal consumption represent total consumtion declines from 2020 through 2039. Losses reflect impacts against national baseline projections and do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

Table 17. Personal Consumption Increases and (Decreases) by Selected Industry, 2020-2039 (in 2019 Billions)

Sector	Consumption Change
Gasoline, Fuel, Energy	$70
Health Care	($448)
Housing, Utilities	($218)
Financial Services, Insurance	($183)
Food Services, Accommodations	($100)
Transportation Services	($90)
Recreational Goods, Vehicles	($83)
Food & Beverages, Off-Premise	($69)
Clothing, Footwear	($65)
Recreation Services	($65)
Furnishings, Household Equip.	($64)
Motor Vehicles, Parts	($55)
Other Services	($280)
Other Nondurable Goods	($129)
Other Durable Goods	($35)
TOTAL	($1.81 Trillion)

Notes: Cumulative losses represent the consumption declines from 2020 through 2039. Losses and increases reflect impacts against national baseline projections, and do not indicate changes from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

5.5 Less Competitive in International Markets

As noted from the discussions of job losses and output, U.S. manufactured products will be less competitive in international markets due to the added costs of transportation. Consequently, between 2020 and 2039, U.S. businesses will lose $446 billion in the value of their exports, while businesses and households will pay an additional $300 billion for foreign imports.

Table 18 shows the cumulative trade effects by quantifying the degree to which exports are expected to decrease and the amount by which imports are expected to increase. By 2029, exports are likely to show an aggregate loss of approximately $64 billion, compared with expected increases of $52 billion in the value of imports. In 2039 alone, due the economic costs imposed by failing to address investment shortfalls, exports are predicted to be $67 billion beneath the baseline, while imports are estimated to be $40 billion above the forecasted baseline.

Table 18. Cumulative Trade Effects ($2019 billions)

Period	Cumulative Export Losses	Cumulative Import Increases
2020-2029	$64	$52
2030-2039	$382	$248
2020-2039	$446	$300

Columns and rows may not add due to rounding. Losses and increases reflect impacts in a given year against total national export projections. These measures do not indicate declines from 2019 levels.
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

Table 18 lists the 10 exported goods and services that stand to lose the most money through 2029 and 2039 as consequences of congested roadways and poor transportation infrastructure. Note that eight of these 10 sectors (other than wholesale trade and petroleum and coal products) are comprised of technology industries and produce intellectual capital as well as high-end products.

Table 19. Potential U.S. Export Reductions in Goods and Services by 2029 and 2039, Ten Largest Affected Sectors ($2019 billions)

Export Sector	2020-2029	2020-2039
Wholesale trade	$6.3	$45.1
Royalties	$2.8	$21.1
Aerospace products and parts	$3.0	$19.5
Architectural, engineering, and related services	$2.3	$19.2
Software	$2.3	$18.6
Other chemicals	$2.8	$18.4
Other financial investment activities	$2.0	$15.5
Scientific research and development services	$1.9	$15.1
Petroleum and coal products	$2.0	$13.8
Other professional, scientific, and technical services	$1.6	$12.2

Note: Changes reflect impacts in a given year against national baseline projections by year from 2020 through 2039. These measures do not indicate changes from 2019 levels. Totals for pharmaceutical products and other chemicals are the sums of two commodity groups, "Pharmaceutical products" and "Other chemicals".
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

5.6 Employment Losses

An underperforming transportation infrastructure will increase costs to businesses. Transporting goods will take more time and require more out-of-pocket expenses for gasoline and vehicle maintenance and increased payment for driver time, leading to unreliable delivery schedules and more expensive costs of goods. In addition, less reliable commuting will lead to overall lower worker productivity on both ends of the workday. These changes will reduce competitiveness of national industries and result in less sales of products and services, which in turn will affect levels of employment across the U.S.

Given current investment practices, capital investment needs, and changing trends in demand, the national losses in employment amount to 378,000 jobs in the year 2029 and 726,000 jobs in 2039. Job impacts are significantly less pronounced than dollar effects. By 2039, the job impacts amount to four tenths of one percent of the projected national baseline, compared to 1.4% of output, 1.1% of GDP and nine-tenths of one percent of disposable personal income.

By 2039, the national population is expected to approach 382 million people. Demand will exist for products and services, even as productivity declines and wages are lowered. Of note, the need for firms to lower costs by reducing employment is mitigated, in part, by the tendency for wage rates to fall as labor productivity weakens. Also, inefficient transportation creates a demand for more truck drivers as it moving products takes longer than it would with an efficient and reliable transportation system, requiring more labor to make trips of similar distances.

Table 20 identifies how job loss because of underinvestment in infrastructure will be distributed. While logistics and retail sectors are expected to provide more jobs in 2039 without adequate transportation investment, professional services, manufacturing, and health care sectors are expected to lose more than 540,000 jobs. These are sectors driven by research and development and highly educated workers, which lead to and support technology advancements These sectors will fall behind international competitors as transportation costs borne by U.S. industries drive prices higher.

Table 20. Potential Employment Losses because of inadequate surface transportation infrastructure, 2029 and 2039

Sector	2029	2039
Logistics	34,600	172,700
Retail trade	(23,300)	16,100
Mining, Utilities, Agriculture	(13,300)	(3,000)
Social Assistance	(7,900)	(9,500)
Transportation Services (excluding truck transportation)	(7,600)	(10,600)
Information	(6,700)	(12,200)
Entertainment	(13,000)	(24,900)
Educational Services	(14,300)	(29,400)
Construction	(30,100)	(48,000)
Finance, Insurance and Real Estate	(31,400)	(66,200)
Accommodation, Food and Drinking Places	(36,400)	(72,300)
Other Services	(47,200)	(97,200)
Professional Services	(42,400)	(136,200)
Manufacturing	(71,300)	(138,000)
Health Care	(67,800)	(267,000)
TOTAL	(378,100)	(725,800)

Columns may not add due to rounding.
Note: Losses and increases reflect impacts in a given year against national projections. These measures do not indicate declines from 2019 levels
Sources: EBP and LIFT model, University of Maryland, INFORUM Group, 2020.

6. Conclusions

The most recent data available shows that current surface transportation system investment trends are unsustainable. Furthermore, this report's findings are likely seriously understated given the COVID-19 pandemic is exacerbating existing shortfalls. The cost of continuing to inadequately fund America's surface transportation system will, at current levels, produce a mounting burden that takes the form of higher costs of doing business, fewer opportunities for firms to invest, a sluggish research and development sector, and less disposable income for households. The burden also compromises America's competitive position in the world's economy and leads to lower overall profitability for business sectors.

This report finds significant and concerning gaps in transit investment – while simultaneously forecasting major roadway congestion in metropolitan areas over the next 20 years. While it's unclear how connected and autonomous vehicles will impact surface transportation system demands – and it's even more uncertain how COVID-19 will permanently change commuting patterns and business travel – overburdened and underperforming bridge, roadway, and transit networks are a certain part of our future if investment trends and practices continue.

These multiple costs of congestion will initiate a chain of economic effects. The costs will be imbedded in the cost structure of production, which in turn will increase prices to U.S. consumers and reduce the competitiveness of domestically goods in the global marketplace. If sales fall in both domestic and international markets, then business income will fall, and household income declines will follow. Lower household incomes will lead to more foregone sales. Compounding these effects, the congestion and detours required by bridge closures will also reduce the purchasing power of households, because goods will cost more, and they will need to pay for excess gasoline and auto repairs.

Solving the infrastructure gap means minimizing congestion and costs to businesses for transporting goods, as well as increasing travel time reliability for commuters, business travelers, and the public. While prescribing specific actions are beyond the scope of this research, it is clear that a combination of investment initiatives focused on state of good repair projects and providing modal options, as well as support of technology developments related to connected and autonomous vehicles, are needed. Failing to do so poses a serious of a risk to the national economy and households in the coming 20 years.

Appendix: Primary Sector Definitions

Primary Sector	Sub-sectors
Manufacturing	Food and beverage and tobacco products, Textile mills and textile product mills, Apparel and leather and allied products, Wood products, Paper products, Printing and related support activities, Petroleum and coal products, Chemical products, plastics and rubber products, Nonmetallic mineral products, Primary metals Fabricated metal products, Machinery, Computer and electronic products, Electrical equipment, appliances and components, Motor vehicles, bodies and trailers and parts, Other transportation equipment, Furniture and related products, Miscellaneous manufacturing
Health Care	Ambulatory health care services, Hospitals, Nursing and residential care facilities
Professional Services	Legal services, Miscellaneous professional, scientific and technical services, Computer systems design and related services, Management of companies and enterprises
Other Services	Administrative and support services, Waste management and remediation services, Other services, except government, Civilian government
Logistics	Wholesale trade, truck transportation, Warehousing and storage
Finance, Insurance and Real Estate	Federal Reserve banks, credit intermediation, and related activities, Securities, commodity contracts, and investments, Insurance carriers and related activities, Funds, trusts and other financial vehicles, Housing services, Other real estate, Rental and leasing services and lessors of intangible assets
Construction	Construction
Retail trade	Retail Trade
Accommodation, food and Drinking Places	Accommodation, Food services and drinking places
Transportation Services (excluding truck transportation)	Air transportation, Rail transportation, Water transportation, Transit and ground passenger transportation, Pipeline transportation, Other transportation and support activities
Mining, Utilities, Agriculture	Farms, Forestry, fishing and related activities, Oil and gas extraction Mining, except oil and gas, Support activities for mining, Utilities
Information	Publishing industries, except internet (includes software), Motion picture and sound recording industries, Broadcasting and telecommunications, Data processing, internet publishing and other information services
Educational Services	Educational services
Entertainment	Performing arts, spectator sports, museums and related activities, Amusements, gambling and recreation industries
Social Assistance	Social assistance