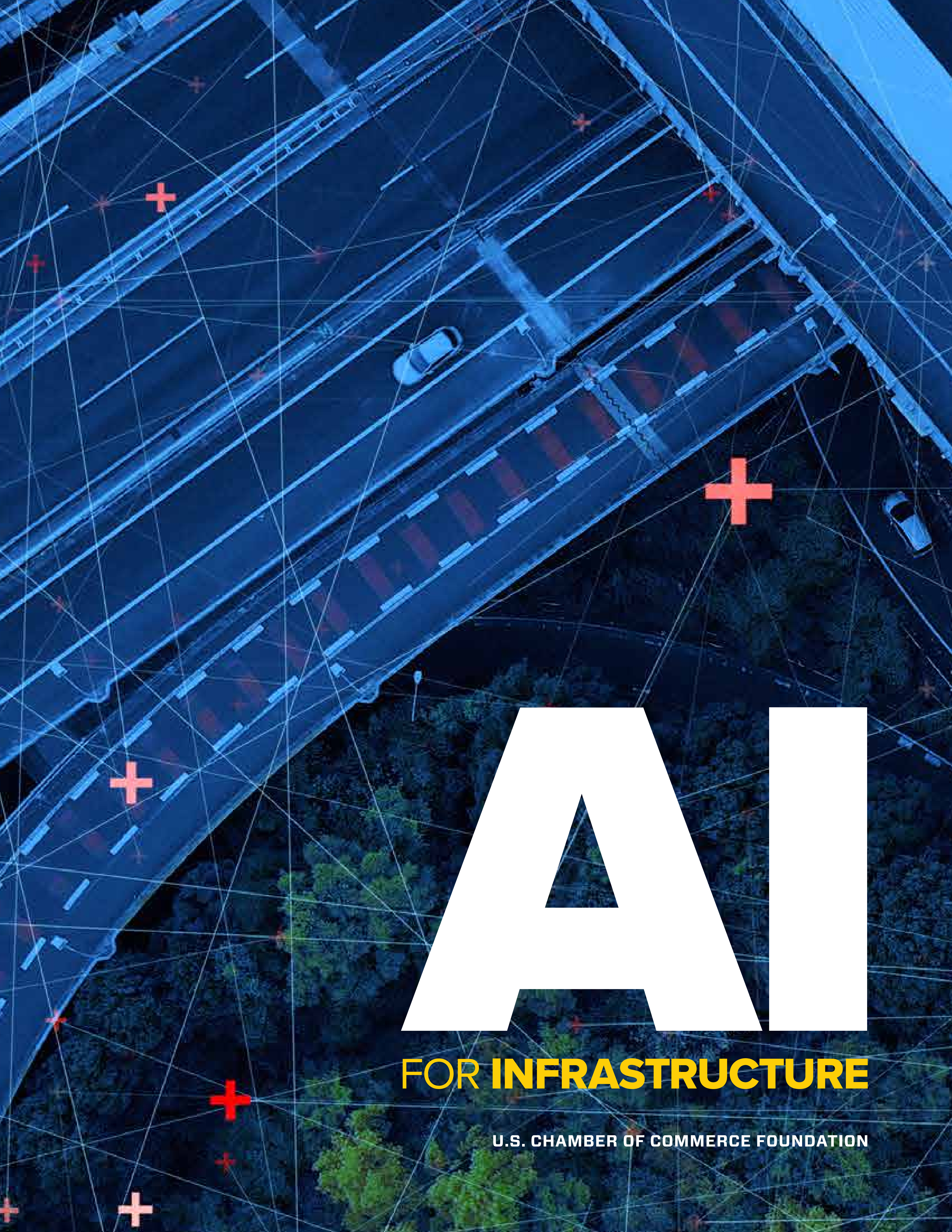
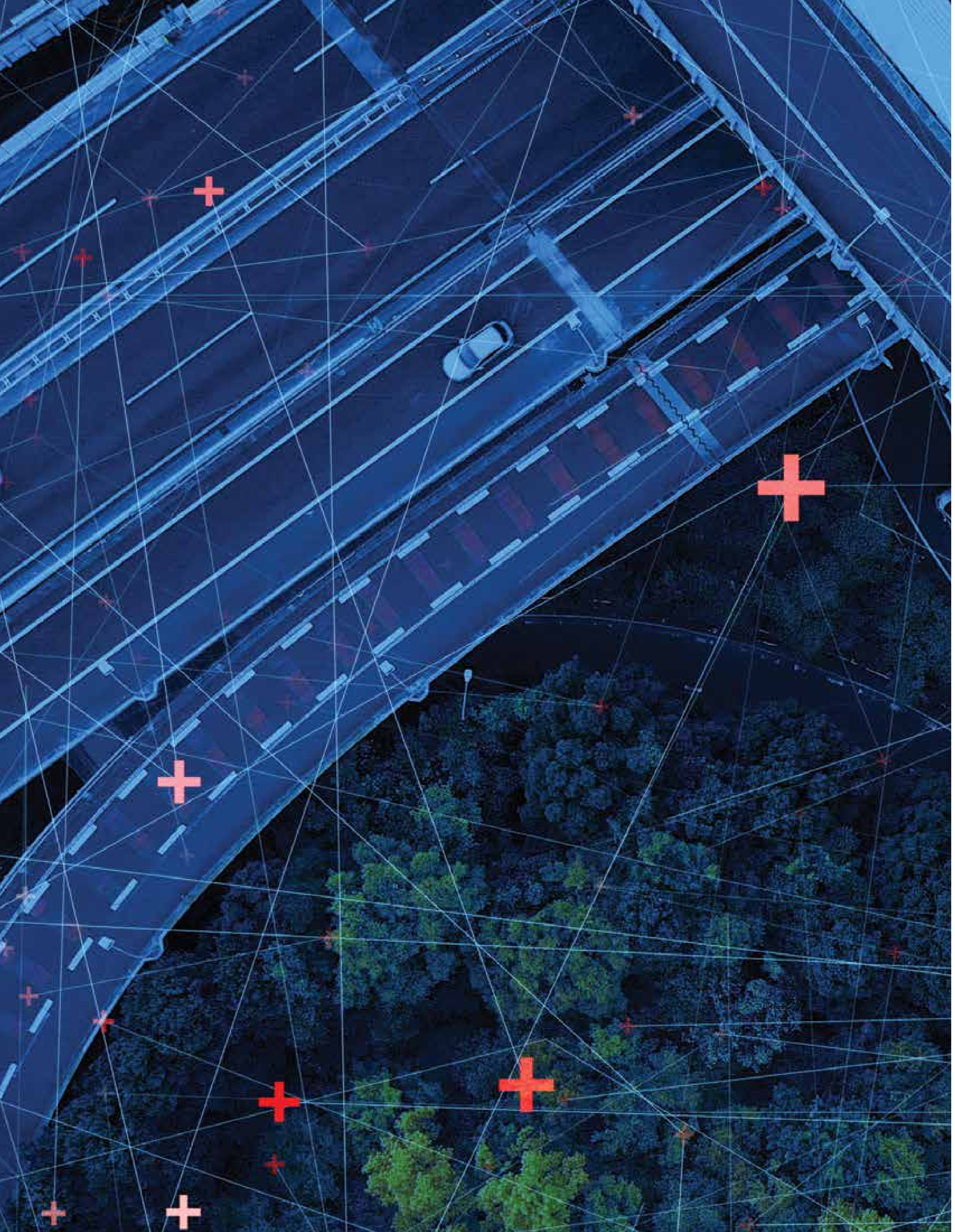


AI FOR INFRASTRUCTURE

U.S. CHAMBER OF COMMERCE FOUNDATION



Workers are gearing up for their return to the office. But are America's roads ready for rush hour?

Commuting hassles are poised to reemerge as workers return to the office. A new AI-powered study ranks the cities where drivers may encounter fewer problems—and notes the places where headaches may be the worst.

INTRODUCTION

Philadelphia's roadways ranked best for road infrastructure in a study of 20 major metropolitan areas by the U.S. Chamber of Commerce Foundation and partner RoadBotics, a Pittsburgh-based tech startup specializing in artificial intelligence (AI). The study's results come at a time when talks about the urgent need for physical infrastructure improvements continue in Washington, D.C., and as America's major metropolitan areas prepare to welcome back millions of commuters who will return to offices and other brick-and-mortar workplaces as America continues its rebound from COVID-19.

Other cities that were studied include some of the country's most populous and historically traffic-plagued cities. Washington and Los Angeles ranked 10th and 17th respectively, sprawling Houston, Texas, ranked 13th, and Phoenix, Arizona, tied with Detroit, Michigan, for the worst of the areas studied at 19th.

The detailed rankings, outlined later in this report, shine a light on the connection between infrastructure investments and economic health —and warn of the long-term impacts that poorly maintained roads and long commutes have on the country's business community, already hard hit by pandemic losses and worker shortages.

THE SITUATION

America's 4 million miles of roads typically see more than 3.1 trillion miles driven annually. That changed abruptly last year when the pandemic forced many states to enact lengthy stay-at-home orders that all but eliminated nonessential travel on roadways.

Fortunately, businesses and employees are rebounding from the disaster. But a return to normalcy means that the infrastructure issues that were pressing before the pandemic—including long daily commutes made worse by poor road conditions and the congestion they cause—will reemerge with urgency once again.

Philadelphia's roadways ranked best for road infrastructure in a recent study of 20 major metropolitan areas by the U.S. Chamber of Commerce Foundation and partner RoadBotics.

As companies prepare their workers to return to offices across the country after Labor Day, business leaders are making the direct connection between reliable roadways and COVID recovery. In short, keeping the nation's roadways in a state of good repair contributes to a robust economy and improves the quality of life for all Americans.

Reliable roadways connect supply chains that keep essential goods and services moving. And stronger roadway systems get people to jobs, medical appointments, and school. Without adequate infrastructure investment in a post-COVID world, our cultural and economic rebound will suffer.

But the challenge with monitoring the condition of infrastructure is twofold. Infrastructure is massive in size and scope and can take hours to days for people to physically observe and assess.

This report examines how private sector innovation can speed up the evaluation process with artificial intelligence, allowing government agencies to better manage transportation staff, road improvement projects, and the overall cost of assessment.

A COST TO EVERY DRIVER

According to TRIP, a national transportation research nonprofit, driving on roads in need of repair costs every driver about $600 a year, and the bill to fix the nation's roads grows higher the longer we defer infrastructure investments.

Finding the budgetary needs required to keep our roadways in a state of good repair is a constant challenge for many local, state, regional, and federal departments of transportation, those primarily responsible for roadway maintenance.

For many cities, the infrastructure maintenance program is only as effective as its budget. For instance, traditional roadway damage and pothole detection rely on both public feedback and routine roadway inspections conducted by transportation agency staff or contractors. This method of finding and assessing potholes is expensive and time intensive, resulting in less frequent inspections that cover limited portions of a community's roadway network. In 2018, state and local governments spent $187 billion on highways and roads.

Of this $187 billion in funding, 24% was sourced from the federal government. The transportation system is critical to the movement of people and goods, making one thing clear: Investing in transportation is one of the most effective ways to spur economic development.

PRIVATE SECTOR INNOVATION TO THE RESCUE

Using a technology like artificial intelligence to assess roadway conditions is a new practice and far less expensive than traditional assessment methods. For example, results showed that it took a Geographic Information Systems (GIS) analyst and road maintenance worker about 600 hours (25 days), at a combined hourly rate of $50 and a total cost of $30,000, to conduct a manual assessment of a 150-centerline mile network. Similar efforts using AI cost half that with the same turnaround time. Instead of agencies manually assessing roadway and pothole damage, roadways can now be visually verified and tracked for repair through AI.

This practice not only accelerates the pavement assessment process, but it also provides actionable data that can be used to provide actual results. These modern tools facilitate faster repairs at a lower cost to taxpayers.

The Foundation partnered with RoadBotics for this study. The RoadBotics platform collects data by mounting a smartphone camera running the RoadBotics app into the windshield of a vehicle. The vehicle drives the road network, allowing the app to collect videos of the pavement. The platform blurs people and cars in the imagery for privacy purposes and then processes the remaining data to identify surface distresses like potholes, cracks, and raveling (a type of pavement distress). The RoadBotics platform assigns a rating to that 10-foot section of pavement and then repeats this analysis for the next section until it has generated a high-definition map of the entire road system.

These maps provide a high level of detail in the form of imagery and objective rating data at each 10-foot interval of roadway. Our findings reveal the story of the complexity of managing and maintaining infrastructure on vast scales.

PUTTING AI TO WORK FOR AMERICA'S ROADS

The 20-city survey collected data aiming to represent a cross-section of major metropolitan areas. The goal was to better understand the relationships and patterns of road conditions. Maps of road quality were generated for about 75 miles of each city, and the areas were chosen to correspond to the downtown area. Therefore, the data analyzed does not reflect the entirety of any city.

This innovative look at America's roadways uses technology to increase awareness of the growing infrastructure crisis, while showcasing the power of private sector solutions.

ANALYZING THE CITIES

Rankings were based on RoadBotics Road Network Score that classified each city's aggregated road classification score within its major business districts. The objective nature of the data allows for easy comparisons between roads within a town or city or even between different cities. The lower the score, the better the roadway network condition. The scores in the rankings are based on a scale, with one being best and five being worst.

1 PHILADELPHIA

As the largest city in Pennsylvania, Philadelphia's Metropolitan Statistical Area (MSA) is home to over 6 million people. As a major city on the heavily traveled I-95 corridor, Philadelphia's transportation infrastructure is critical to the movement of people and goods in the mid-Atlantic region. The analysis of 71 road miles in Philadelphia scored the highest of all cities in our analysis with an overall score of 1.74, indicating the well-maintained street surfaces. This score may be attributed to a high average revenue per capita value of $1,145.

2 JACKSONVILLE

Our study rated Jacksonville, Florida, as number two for its business district roadway network. The city boasts a healthy 6.1% growth in tax revenue with a booming population to complement its healthy roadway network. The 75 miles surveyed showed that most motorways scored exceptionally well with only 8% of their links rating no worse than 2.00. This is even more impressive as Jacksonville's modest tax revenue was $1.25 billion in 2019, ranking it 16 out of 19 for the major metropolitan areas considered in this study.

3 NEW YORK CITY

New York City is America's most populous city with an MSA population of 19 million people in 2019. As a critical hub for both freight and person travel, New York City's transportation system management requires the oversight of multiple components such as highways, rail transit, bus transit, ports, commuter rail, freight rail, several international airports, pedestrians, and bicycles. The evaluation of 73 miles of roadway in New York City resulted in a score of 1.85, good enough for ranking third among the cities in our study. Recognizing the need to support a complex, high-volume transportation network, New York City has by far the highest city revenue at nearly $300 billion in 2019.

3 DENVER

Denver tied for third. Since 2010, Denver's city population has grown by over 21% and has benefited from an annual revenue growth rate of over 9% between 2017 and 2019. Denver's growth presents both opportunities and challenges, including an increased number of vehicles on the roadways. The 76 miles of roadway network evaluated resulted in a Roadway Network Score of 1.85. Of the roadways surveyed, only 3% of the road links were rated higher than a 3.00. Based on Denver's increasing growth and large geographical boundary, the city may have challenges expanding and improving on its roadway network in the future.

5 NASHVILLE

Nashville, Tennessee's capital city, comes in at number 5 in our rankings. The growing city has seen over 1% annual capita growth since 2017, while its tax revenue has increased 5% per annum. Though Nashville maintains a reliable transportation network, recent analysis categorizes its 70 miles within a range of 1.70-2.37 for its various corridors. Most notably, Nashville's lowest rated corridors are its primary linkages. These middle-grade zones may provide the highest return on investment for roadway maintenance.

6 SAN FRANCISCO

San Francisco is a national tech hub and California's second most populous MSA region with 4.7 million residents. With one of the highest highest costs of living, San Francisco has benefited from the largest city revenue growth, 12.5%, of all cities in our analysis. Investments in maintaining the 75 road miles in our study resulted in a score of 2.03 and the number 6 ranking.

7 CHICAGO

As the largest city in the Midwest, with over 9.5 million residents, Chicago is well known for having a high-functioning and extensive transportation system. However, since 2017, Chicago has had the second highest population decrease (-0.2%) and the lowest tax revenue growth rate (0.9%) of all the cities analyzed. The 72 roadway miles studied resulted in a Road Network Score of 2.11, giving the Windy City the seventh best infrastructure ranking. But the loss in tax revenue and population could be an issue in how the roadway network is maintained in future years.

8 CHARLOTTE

Charlotte is the second largest city in the South and North Carolina's largest urban area. Of all the cities studied in this analysis, Charlotte has had the second highest population increase (2.4%) and the sixth highest annual revenue growth rate (7.2%). With a Road Network Score of 2.16, Charlotte ranks eighth on the list. With average revenue per capita at $440, Charlotte's 70 roadway miles could be seeing a lot more money in the future based on current trends.

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Other populous and traffic-plagued cities like Washington and Los Angeles ranked 10th and 17th, respectively.

9 SAN ANTONIO

The San Antonio MSA is the third most populous region in the state of Texas with close to 2.5 million people. With a city revenue growth rate of 4.6%, San Antonio had a total city revenue of $2.2 billion in 2019. With the average revenue per capita at $849, the 73 roadway miles in San Antonio resulted in a rank of 9 with a score of 2.21.

10 WASHINGTON, D.C.

The nation's capital is a focal point of history, policy, and political movements. It has a mix of transportation and commercial activity. Our findings rank D.C. among the middle of the pack at number 10 with a score of 2.38. Most corridor links scored well, ranging from 2.00 for residential streets to 2.60 for service corridors. Washington benefits from significant federal grants that ensure the downtown business district is well maintained. In response to the well-maintained core business district, the city saw its annual city revenue grow by 5.4% per annum. The District Department of Transportation deployed over $93 million in 2017 to maintain and grow its 1,100-mile roadway network.

10 BOSTON

Boston, the capital of Massachusetts, is the major center of economic and cultural life for New England. It is the hub of a metropolitan region that extends well into its neighboring states. With an MSA population of 4.8 million residents and a tax revenue of over $3.2 billion, Boston ranks 10th in this analysis. Of the 72 roadway miles surveyed, nearly a third of the network ranks at 3 or higher, contributing to its 2.23 Road Network Score.

12 MINNEAPOLIS

Minnesota's largest city lands at number 12 in our ranking. Our data was collected from both Minneapolis and twin city Saint Paul to better understand the region's state of repair. Nearly 30% of Minneapolis' roadway corridors rated Tier 3, though its primary roadway networks scored very well with 96% classified as Tier 1. This tells us that Minneapolis is adept at moving vehicles through its corridors, but there may be significant opportunities to encourage business activity along secondary and tertiary zones. Ranking 18th in tax revenue growth and 13th in population growth lines up with the data collection assessment as well.

13 HOUSTON

With an MSA population of 6.8 million residents and an MSA land area of 9,444 square miles, Houston is larger than the State of New Jersey. Of the cities studied in this analysis, Houston ranks second lowest in revenue growth rate at 1.8%, but has the fifth highest population growth at 1.9%. With an average revenue per capita at $353, the 75 roadway miles resulted in a rank of 13 with a score of 2.31.

14 SEATTLE

Seattle is a major hub for international goods and people movement. With an MSA population of over 3.8 million residents, the city has a revenue of over $2.5 billion. The challenging weather conditions may contribute to the score of 2.32 on the 72 road miles analyzed in our study, resulting in a ranking of number 14.

14 COLUMBUS

Ohio's capital city comes in at number 14 in the rankings. As the city's population (2.1 million) and annual tax revenue ($1.6 billion) continue to grow, Columbus will need to look for ways to improve its 75 roadway miles analyzed at the Roadway Network Score of 2.32. Currently, over a third of Columbus' roadway network falls at a rating of 3 or higher. This score is in large part a reflection of its *residential* roadway network that encompasses nearly 39 of the total 75 miles and has a rating of 2.36.

16 SAINT PAUL

Saint Paul, separated by only 7 miles and the Mississippi River from Minneapolis, ranks number 16 in our assessment. Nearly 40% of its secondary roads, where primary commercial activity is located, rate as Tier 3. Like Minneapolis, over 90% of its primary roadway network rates Tier 1, showing an aptitude for moving vehicles through Minnesota's second largest city. We expect that modest investment in roadways through business nodes may encourage retail and similar type activity.

17 LOS ANGELES

Los Angeles boasts an economy that is larger than all of Sweden. This, in turn, places great stress on the local transportation network, ranking 17 in our study. Los Angeles' nearly $20 billion in annual revenue is distributed across a huge number of city services, including health, transit, safety, and, of course, transportation. Our study notes that only 11% of its roadway corridors are considered Tier 1, none of which are considered primary roadway links. Further work connecting this business zones through mega projects, such as Metro's Purple line, look to improve safety and build economic activity centers.

17 OKLAHOMA CITY

As the largest city in Oklahoma and the state capital, Oklahoma City has an MSA population of 1.4 million, the smallest of the cities in our analysis. Consistent with the population, city revenue for Oklahoma City is the second smallest at $927.7 million in 2019. The measurement of 74 roadway miles results in a score of 2.38, tied with Los Angeles for the number 17 rank.

19 PHOENIX

Phoenix is by far the largest city in Arizona with a 2019 population of 1.6 million and 4.7 million MSA residents. It also has a moderate revenue growth rate of 5.7% with a 2019 city revenue just under $2.6 billion, resulting in an average revenue per capita of $520. The evaluation of 75 roadway miles in Phoenix generated a score of 2.57, tied for the number 19 rank with Detroit.

19 DETROIT

Detroit comes in at number 19, tied with Phoenix. Detroit's population growth rate sits at 0.2% annually—tied for the second lowest compared with all cities analyzed—and has an MSA population of 4.3 million residents as of 2019, making it the largest metropolitan area in Michigan. Detroit was the first city in the U.S. to install a mile of paved concrete, which is especially appropriate as Detroit is best known as home to the U.S. automotive industry. With a revenue growth rate of 6.2% and an average revenue per capita of $323, the 73 roadway miles resulted in a score of 2.57.

KEY INSIGHTS FOR AMERICA'S LOCAL, STATE, AND FEDERAL LEADERS

U.S. infrastructure is crumbling. With our country on the cusp of new transportation demands, the need to collect quality data on the safety, mobility, reliability, and sustainability of the transportation system has never been greater.

Traditional data collection methods such as traffic detectors, closed circuit television (CCTV) feeds, and incident data require transportation agencies to install, operate, and maintain equipment to measure the performance of the transportation system. While these methods still play a critical role in transportation system monitoring and management, recent technology enhancements are driving a change in how transportation professionals collect and analyze data. Leading professionals are integrating this data with macroeconomic information to enhance and plan regional business activity.

These enhancements are creating new opportunities for transportation agencies to collaborate with nontraditional entities—as well as the public—to improve transportation systems and stimulate economic growth. Agencies are using these AI data collection methods across roadway, transit, and fixed rail. This data collection not only provides key insights to agencies, but it also provides innovative modeling for record keeping.

Imagine deploying a Light Detection and Ranging (LIDAR) drone over a bus depot to establish facility dimensions while considering an expansion. This can be carried out for a few thousand dollars instead of mobilizing an entire field crew to collect the same data. Agencies then draft conceptual designs and calibrate financial models to figure out what impacts a facility improvement may have on the traveling public. What once took months can now be done in weeks, catalyzing transit-oriented development and delivering faster economic growth.

Figure A: Connected and Automated Vehicle Concept (USDOT, 2017)

New companies are using roadway data collection to optimize agency budgets. Other sample technologies include connected and automated vehicles (CAV) and location-based services (LBS). CAV technologies such as in-vehicle radar sensors, cameras, and warning systems are designed to help motorists detect safety hazards. In some vehicles, the response to detected hazards is automated (automatic braking). To support these functions, massive amounts of high resolution data are collected from on-board sensors. A representation of a hypothetical CAV environment is presented in Figure A.

While the original design of these technologies was for real-time and near-future predictive applications, transportation professionals are creating tremendous value from archived CAV data. This data is supplying first-of-its-kind observations of individual vehicle kinematics, acceleration/deceleration, braking, horsepower, fuel consumption/energy use, seatbelt usage, steering angle, etc., collected in real-world driving environments.

Such data is enabling transportation analysts to better understand human factors and

Figure B: Trajectory Data of a Single Trip (Ayers, 2020)

proactively show driving environments with poor or degrading safety performance. This data can then be used to activate business districts.

Further awareness of traffic operations allows the safer integration of vehicles and pedestrian areas, exemplified by Las Ramblas in Barcelona or the Kensington High Street shopping district in London. These business zones have seen significant increases in pedestrian foot traffic with a reduction in traffic fatalities. This shows the win-win relationship of such planning efforts.

Location-based services (LBS) refer to technologies that use high resolution geographic data to provide specific services to end users. Examples of LBS are smartphone apps that provide route guidance or information about a specific geographic area based on the time-stamped location of an LBS-equipped device.

Like CAV applications, transportation professionals are using the data from LBS technologies to collect real-time information on transportation system performance and real-world travel behavior patterns. The two primary data products stemming from LBS technologies for transportation analysis are trajectory data and probe data.

Trajectory data is a series of time-stamped latitude and longitude coordinates (stripped of personally identifiable information) that reconstruct an individual trip. This data can be used to derive a trip's start location (i.e., origin), end location (i.e., destination), route taken, inferred mode(s) of travel, and total trip time. Figure B presents a visualization of trajectory data used to reconstruct an individual vehicle trip, while Figure C shows a sample analysis of a full trajectory dataset (thousands of individual trips) indicating route usage (orange and blue routes) between a specific origin (orange) and destination (blue) geography.

The second transportation data product from LBS is probe data. Probe data is an aggregation of trajectory data and most applied to the

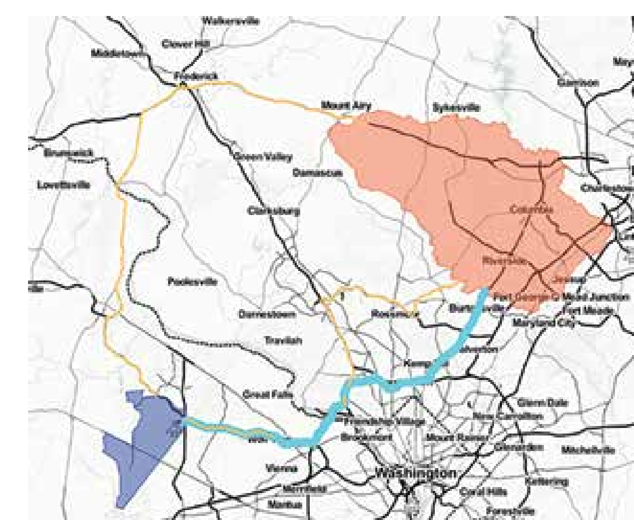

Figure C: Route Analysis Using Trajectory Data (CATT Lab, 2021) driving mode to provide estimated travel times and speeds on predefined road segments. Real-time applications of probe data include travel time estimation and road network mobility performance. This information is often used by transportation agencies to provide travel information on dynamic signs, such as the one seen in Figure D.

AI IN TRANSPORTATION: THE TECHNICAL DETAILS

AI uses deep-learning techniques to analyze each video frame captured while conducting a roadway assessment. Based on the images captured of the road surfaces and their varying color factors, AI can identity every aspect of the road surface—from giant potholes to more nuanced factors such as bumps, depressions, and cracks. AI can do this as well, if not better, than a human.

Recent advances in AI have created new paths in transportation research and analysis. Two examples of transportation AI applications include network-level traffic volume estimation and trip routing from sparse trajectory data.

Traffic volumes are traditionally measured at point locations using permanent sensors (loop detectors or roadside radars, Figure E) or temporary count stations, such as pneumatic tube counters (Figure F). While these traffic volume tools provide valuable information, they inherently limit the spatial coverage of traffic volume measurement. Given the cost to install, operate, and maintain these sensors, many agencies are turning to AI applications to estimate traffic volumes on road segments not equipped with traffic count technologies. In doing so, transportation agencies can more comprehensively monitor and analyze the performance of the transportation system.

Figure D: Travel Information Signs (INDOT, 2021)

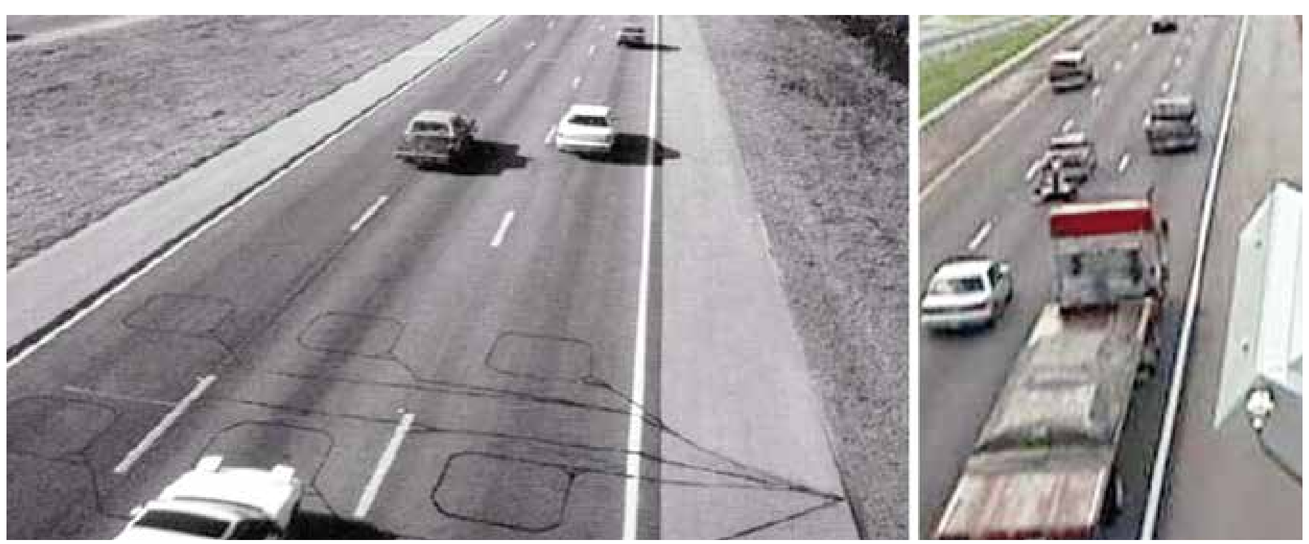

Figure E: Field deployed inductive loop (left) and roadside acoustic sensor (right) (FHWA, 2003)

The second example of AI in action is inferring trip routes from imprecise or sparse trajectory data. This is especially valuable information because it helps agencies identify where people choose to live, work, and socialize. Building infrastructure along these corridors brings new commercial activity incredibly quickly as people already wish to access these nodes.

In some instances, data from LBS technologies can be geographically imprecise or interrupted. These interruptions can cause data gaps that make trip routing analysis challenging if not impossible. To overcome this challenge, researchers have developed AI techniques to map imprecise points to the transportation network (such as a road segment or transit line) in a process called snapping. They can then infer the most likely route taken between consecutive data points in a process called routing, using historical similar trips and traffic conditions at the time of the trip. Figure G illustrates the general concept of snapping and routing. These techniques allow transportation analysts to maximize the use of this valuable data that otherwise would be considered unusable.

Figure F: Pneumatic Tube Traffic Counters (TNDOT, 2021)

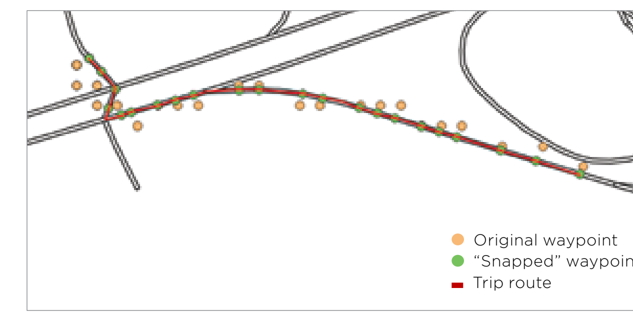

Figure G: Visualization of Trajectory Data Snapping and Routing

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The transportation system is critical to the movement of people and goods, making one thing clear: Investing in transportation is one of the most effective ways to spur economic development.

This innovative look at America's roadways uses technology to increase awareness of the growing infrastructure crisis while showcasing the power of private sector solutions.

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REFERENCES

Ayers, R. Map Based Time-Space Cube of Vehicle Trajectory Data in ArcGIS. Internal CATT Lab Exploratory Analysis. December 2020.

District Department of Transportation. "DDOT by the Numbers." Available at: https://ddot.dc.gov/page/ddot-numbers. Accessed January 14, 2021.

Franz, M. L. Route Analysis between Howard County, MD and Dulles Airport, VA. Internal CATT Lab Analysis. January 2021.

Hedges & Company, "How Many Drivers are there in the US" (2019). https://hedgescompany.com/blog/2018/10/number-of-licensed-drivers-usa/

Indiana Department of Transportation (INDOT). Travel Information Signs. Available at - https://www.in.gov/indot/3251.htm. Accessed January 15, 2021.

Jaffe, E. "Places Where Cars Bikes and Pedestrians All Share the Road." Bloomberg City Labs. https://www.bloomberg.com/news/articles/2015-03-23/6-places-where-cars-bikes-and-pedestrians-all-share-the-road-as-equals. Accessed January 12, 2021.

Kans Law Firm. "Little Known Facts – Minnesota Twin Cities." Available at: https://www.dwiminneapolislawyer.com/resources/little-known-facts-minnesotas-twin-cities/. Accessed January 12, 2021.

Mental Floss. "Things You Might Not Know About Los Angeles." Available at: https://www.mentalfloss.com/article/54172/25-things-you-might-not-know-about-los-angeles. Accessed January 16, 2021.

Tennessee Department of Transportation (TDOT). Traffic Data. Available at: https://www.tn.gov/tdot/long-range-planning-home/longrange-road-inventory/longrange-road-inventory-traffic.html. Accessed January 15, 2021.

United State Department of Transportation -Federal Highway Administration. Leveraging the Promise of Connected and Autonomous Vehicles to Improve Integrated Corridor Management and Operations: A Primer. FHWA HOP-17-001. Washington, D.C. January 2017.

United State Department of Transportation -Federal Highway Administration. Freeway Management and Operations Handbook. Washington, D.C. 2003.

United State Department of Transportation-Federal Highway Administration–Travel Monitoring. Available at: https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm?CFID=153434347&CFTOKEN=4c2a911a2693a099-BD46DDF7-0B8E-C7C2-2F4B21311FF143CA. Accessed January 15, 2021.

TRIP. "Key facts about the U.S. surface transportation system" Available at: https://tripnet.org/wp-content/uploads/2020/04/TRIP_Fact_Sheet_NATL.pdf. May 2021.

Urban Institute – State and Local Finance Initiative. Highway and Road Expenditures. Available at: https://www.urban.org/policy-centers/cross-center-initiatives/state-and-local-finance-initiative/state-and-local-backgrounders/highway-and-road-expenditures. Accessed July 7, 2021.