United States Government Accountability Office

Report to Congressional Committees

July 2022

NATIONAL HIGHWAYS

Analysis of Available Data Could Better Ensure Equitable Pavement Condition

GAO-22-104578

GAO Highlights

Highlights of GAO-22-104578, a report to congressional committees.

Why GAO Did This Study

The National Highway System is key to the nation's economy, defense, and mobility. It comprises approximately 220,000 miles of roads and accounts for about 54 percent of all vehicle miles traveled. Poor pavement condition on National Highway System roads could pose safety issues and impede the flow of traffic.

House Report 116-106 included a provision for GAO to review issues related to pavement condition of the National Highway System.

This report assesses the extent to which: (1) pavement condition varies on the National Highway System and (2) FHWA assesses National Highway System pavement condition within states, such as at the local level.

GAO analyzed pavement condition data from FHWA and other publicly available data sources and developed a statistical model to assess variation in pavement condition by community characteristics. GAO also reviewed applicable statutes, regulations, and agency documents and interviewed FHWA officials to understand the extent to which FHWA assesses pavement condition.

What GAO Recommends

GAO is making two recommendations, including that FHWA analyze data on pavement condition within states and identify strategies to help states detect and address issues contributing to differences in pavement condition affecting certain areas and communities. DOT partially concurred with the recommendations and noted steps FHWA planned to address them.

View GAO-22-104578. For more information, contact Elizabeth Repko at (202) 512-2834 or repkoe@gao.gov.

July 2022

NATIONAL HIGHWAYS

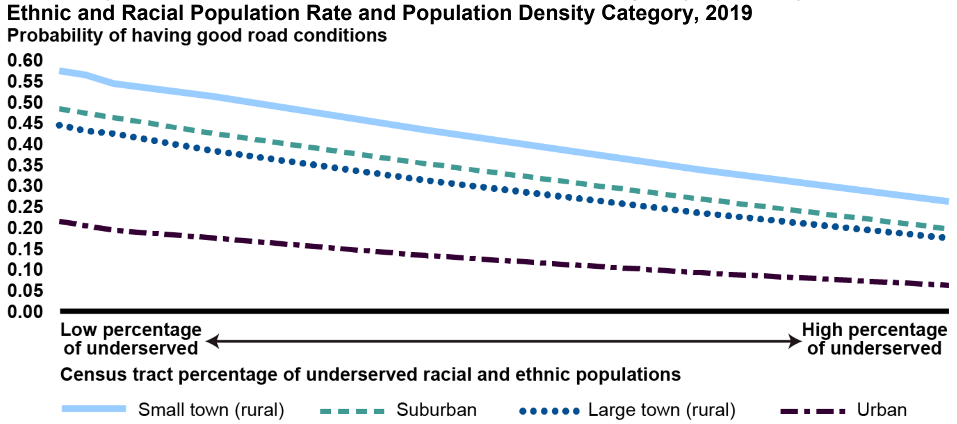
Analysis of Available Data Could Better Ensure Equitable Pavement Condition

What GAO Found

Most pavement on the National Highway System is in good or fair condition, but the condition varies widely across and within states. Moreover, GAO found that pavement condition varies based on certain community characteristics. Even when controlling for factors such as climate type and traffic density, pavement is less likely to be in good condition on roads in census tracts with:

- higher percentages of underserved racial and ethnic populations—communities facing systemic barriers in accessing available benefits and opportunities (see figure);
- higher family poverty rates; and
- urban areas.

Probability of Pavement in Good Condition on the National Highway System by Underserved Ethnic and Racial Population Rate and Population Density Category, 2019



Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Note: Data for 2019 were the most recent full year of available data at the time of our analysis. For more details, see fig. 12 in GAO-22-104578.

The Federal Highway Administration (FHWA) assesses whether states are making progress toward state-wide pavement condition targets. However, FHWA does not regularly examine data to assess pavement condition within states, such as at the local level. The Department of Transportation (DOT) and FHWA have strategic goals and objectives related to safe, efficient, and equitable transportation. Most transportation stakeholders GAO interviewed noted that pavement in good condition is safer or more efficient for travel. Because FHWA has generally not analyzed data about pavement condition at the local level, it lacks awareness of issues that could pose risks to its strategic goals, such as concentrations of poor pavement condition or differences across communities.

In response to executive orders, DOT is determining how to assess equity impacts for all of its programs, but, as of June 2022, has not identified what pavement-specific analyses it will conduct, if any. Additional analyses of poor pavement concentrations and the differences by community characteristics could help FHWA understand why these conditions are occurring. These analyses could also help FHWA identify strategies to help ensure that all communities have safe and equitable pavement conditions.

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Figures

Abbreviations

ACS	American Community Survey
ARNOLD	All Road Network of Linear Referenced Data
DOT	Department of Transportation
ERS	Economic Research Services
FHWA	Federal Highway Administration
HPMS	Highway Performance Monitoring System
IIJA	Infrastructure Investment and Jobs Act
IRI	International Roughness Index
LTPP	Long-Term Pavement Performance
MAP-21	Moving Ahead for Progress in the 21st Century Act
MERRA-2	Modern-Era Retrospective Analysis for Research and Applications, Version 2
MPO	metropolitan planning organization
NASA	National Aeronautics and Space Administration
NHPP	National Highway Performance Program
NHS	National Highway System
PM2	Performance Measure Rule 2
RTPO	Regional Transportation Planning Organizations
RUCA	Rural-Urban Commuting Area
state DOT	state department of transportation
STIP	state transportation improvement program
SVI	Social Vulnerability Index
TAMP	transportation asset management plan
TIP	transportation improvement program
USDA	US Department of Agriculture

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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July 28, 2022

The Honorable Brian Schatz
Chair
The Honorable Susan Collins
Ranking Member
Subcommittee on Transportation, Housing and Urban Development, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable David E. Price
Chairman
The Honorable Mario Diaz-Balart
Ranking Member
Subcommittee on Transportation, and Housing and Urban Development, and Related Agencies
Committee on Appropriations
House of Representatives

The National Highway System is key to the nation's economy, defense, and mobility. It comprises approximately 220,000 miles of roads, and accounts for about 54 percent of all vehicle miles traveled. As such, it runs through a wide variety of landscapes and neighborhoods, including rural areas, major metropolitan areas, and urban cores. Depending on where people live and travel, they may encounter different pavement conditions on the National Highway System. Keeping National Highway System pavement in good condition is essential to ensuring the safe and efficient movement of people and goods.

Enacted in November 2021, the Infrastructure Investment and Jobs Act (IIJA) authorized an annual average of about $54.6 billion in funding for fiscal years 2022 through 2026 for the federal-aid highway program.[1] Through this program, the Department of Transportation's (DOT) Federal Highway Administration (FHWA) provides funding to state departments of

[1]Pub. L. No. 117-58, § 11101(a)(1), 135 Stat 429, 443 (2021). This amount of funding represents a $13.2 billion increase from the annual average of about $41.4 billion authorized for fiscal years 2016 through 2020 under the last major surface transportation reauthorization act. Fixing America's Surface Transportation Act, Pub L. No. 114-94, § 1101(a)(1), 129 Stat. 1312, 1322 (2015).

transportation (state DOTs) to preserve, build, and improve the nation's roadways and bridges, on and off the National Highway System. For the purposes of the federal-aid highway program, a state is defined as any of the 50 states, the District of Columbia, or Puerto Rico.[2] Thus, there are 52 state DOTs.

Issued in March 2022, DOT's strategic plan for fiscal years 2022 through 2026 notes the department's intention to deliver a safe, equitable, and reliable transportation system. The plan includes strategic goals of safety and equity, citing the need to invest in underserved communities and to reduce inequities in transportation systems and disparities in safety outcomes. The plan also highlights the importance of reliability in the transportation system and keeping core assets, including pavement on the National Highway System, in a state of good repair.

DOT's Equity Action Plan notes that prior transportation policy and investment decisions have led to decades of infrastructure inequities in historically overburdened and underserved communities. Executive Order 13985, issued in January 2021, generally directs federal agencies to assess whether members of underserved communities face systemic barriers in accessing benefits and opportunities available under the agencies' policies and programs and whether agency action may be necessary to advance equity in their programs.[3] For the purposes of this report, we use the term "underserved racial and ethnic populations" to include Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino populations. We created this term based on the Executive Order's definition of "underserved communities" and the Census race and ethnicity categories.

[2]23 U.S.C. § 101(a)(28).

[3]Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, Exec. Order No. 13985, § 5 (Jan. 20, 2021). The executive order defines equity as, "the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality."

House Report 116-106 included a provision for GAO to review issues related to the pavement condition of the National Highway System.[4] This report assesses (1) the extent to which pavement condition varies on the National Highway System and (2) the extent to which FHWA assesses the pavement condition of the National Highway System within states, such as at the local level.

To assess the extent to which pavement condition varies on the National Highway System, we reviewed applicable statutes and regulations related to pavement condition and FHWA's collection of pavement data from states. We obtained geospatial data from FHWA on National Highway System pavement condition and traffic density for calendar year 2019.[5] We also used data from the Census Bureau and the U.S. Department of Agriculture to obtain census tract-level data on community characteristics, which we define as (1) family poverty rate, (2) race and ethnicity, and (3) population density.[6]

We conducted two types of analyses with these data. We first analyzed and mapped the data to determine how pavement condition varied across the nation. We then developed a statistical model to assess the extent to which pavement condition was associated with community characteristics.[7] Through interviews (described below) and literature

[4]H.R. Rep. No. 116-106, at 33-34 (2019).

[5]The source of the data is FHWA's Highway Performance Monitoring System (HPMS). HPMS is a national level highway-information system that includes data on the condition, performance, use, and operating characteristics of the nation's highways. HPMS includes data for all 52 state DOTs. Data for 2019 were the most recent full year of available data at the time of our analysis.

[6]"Community" refers to census tracts. We use the term "population density" when referring to how urban or rural an area is. To measure this, we used the U.S. Department of Agriculture's Rural-Urban Commuting Area codes, which classify census tracts using measures of population density, urbanization, and daily commuting. Census tracts were assigned one of the following labels: urban, suburban, rural large town, or rural small town. These classifications differ from the statutory definitions of "rural" and "urban" areas applicable to the federal-aid highway program.

[7]For the purposes of this report, we measured population income by the percentage of families in poverty in a census tract, race and ethnicity by percent of the population that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino, in a census tract, and population density by whether a census tract is an urban, suburban, rural large town, or rural small town according to the U.S. Department of Agriculture's 2010 Rural-Urban Commuting Area classification.

reviews, we identified factors that affect pavement condition, such as climate and traffic density. We obtained climate data from the National Aeronautics and Space Administration and used the data and FHWA's traffic data to control for those factors in our model.[8]

To assess the reliability of the FHWA data, we interviewed FHWA officials, reviewed relevant documentation, and performed standard data checks, where appropriate. We determined the data, including the data for factors such as climate and traffic, were reliable for our purposes of mapping pavement condition and statistically analyzing pavement condition, including controlling for factors such as climate and traffic. For more details on our data analyses, see appendix I.

We also interviewed officials about national and state pavement condition and factors that affect pavement condition, including officials from: FHWA, six state DOTs, 11 metropolitan planning organizations, and two regional transportation planning organizations. We selected the six states and 11 metropolitan planning organizations to ensure variation in location, population density, racial and ethnic population, and family poverty rate. Views of selected officials are not generalizable. We also interviewed representatives from relevant stakeholder organizations, such as the American Association of State Highway Transportation Officials. For a complete list of organizations we interviewed, see appendix II.

To assess the extent to which FHWA analyzes National Highway System pavement condition within states, we reviewed applicable statutes and FHWA regulations, policies, and guidance. We also reviewed Executive Order 13985 and the DOT request for information regarding equity in surface transportation programs.[9] We spoke with FHWA officials who oversee the National Highway System pavement data, as well as DOT officials responsible for DOT's response to Executive Order 13985. We found that a principle of internal control, as outlined in *Standards for Internal Control in the Federal Government*—namely, that management should use quality information to achieve the entity's objective—was significant to our review of whether FHWA analyzed pavement data within

[8]We included several traffic variables in the statistical model to control for traffic from different types of vehicles, including traffic for single unit and combination trucks.

[9]Request for Information on Transportation Equity Data, 86 Fed. Reg. 28,189 (May 25, 2021).

states.[10] We assessed FHWA's use of pavement condition data against this principle, in particular that management should design a process that uses the entity's objectives and related risks to identify the information requirements needed to achieve the objectives and address the risks. We reviewed DOT and FHWA strategic plans to identify strategic goals that would be informed by granular analyses of pavement condition data.

We conducted this performance audit from October 2020 to July 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

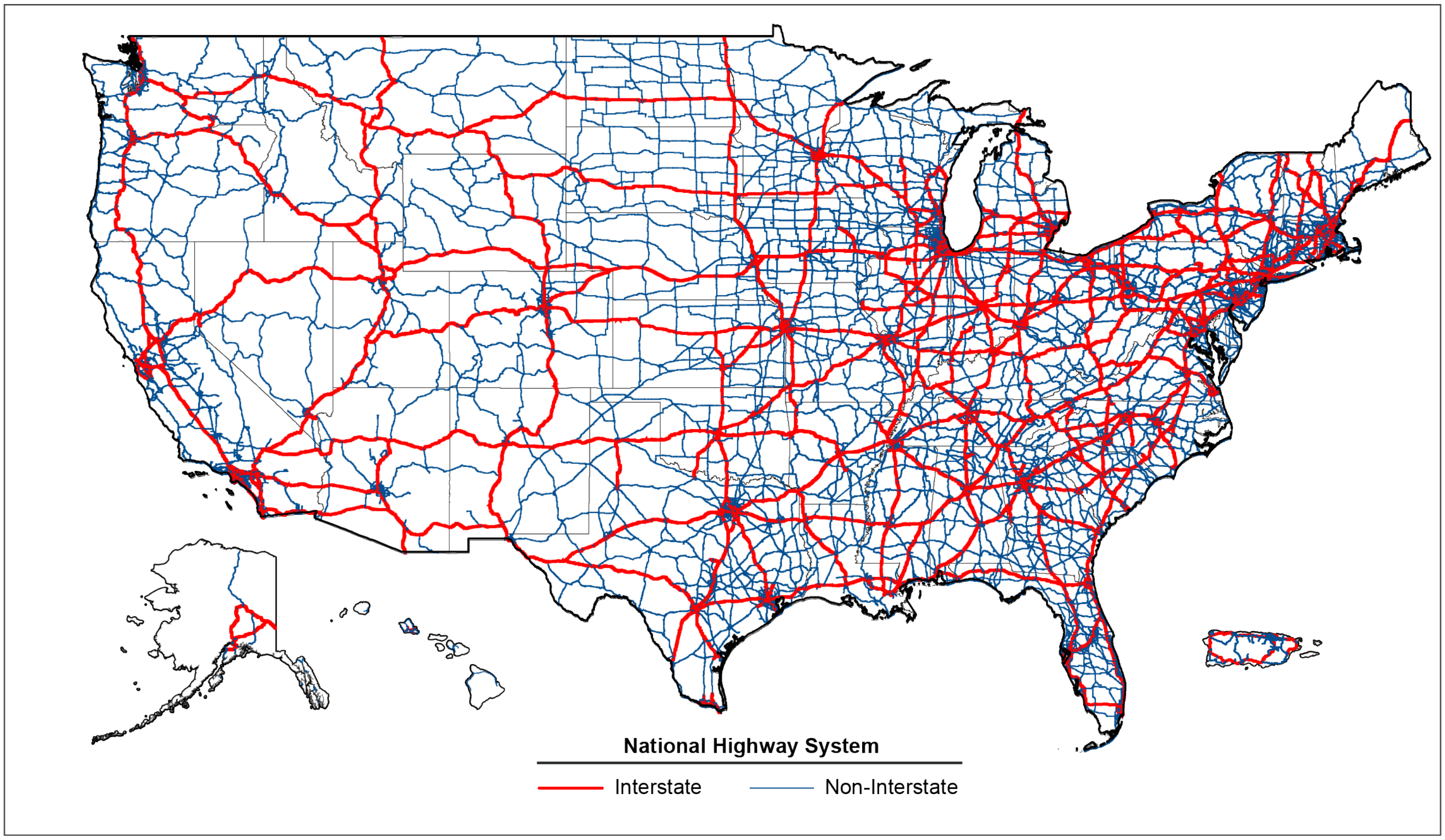
Background

The National Highway System

The National Highway System consists of approximately 220,000 miles of public roads, including the 49,000-mile Interstate System as well as non-Interstate highways. (See fig. 1).

[10] GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

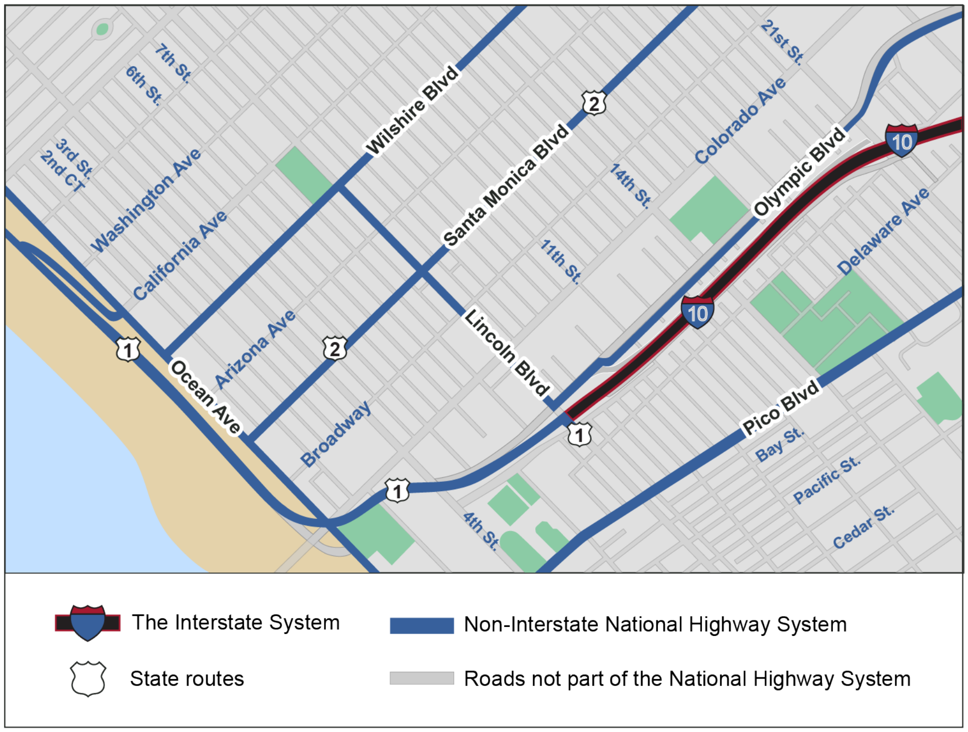
Figure 1: Map of the National Highway System



Source: GAO analysis of Federal Highway Administration data. | GAO-22-104578

The National Highway System also includes other types of roads, including state routes, roads that provide access to major population centers, public transportation facilities, airports, ports, and roads that traverse cities and suburbs. Figure 2 shows an example of various types of National Highway System roads in Santa Monica, California.

Figure 2: Example of National Highway System Roads in Santa Monica, California



Source: GAO, Federal Highway Administration's HEPGIS data and referenced google maps. | GAO-22-104578

Note: This figure provides an example of the types of Interstate and non-Interstate roads that are part of the National Highway System.

The Federal Aid Highway Program

FHWA is responsible for administering the federal-aid highway program, an umbrella term for a collection of grant programs. States receive funding through the federal-aid highway program to build, preserve, and operate the nation's highway and bridge infrastructure, including that on the National Highway System. The National Highway Performance Program is the primary source of federal-aid highway program funding to support the condition and performance of the National Highway System.[11] While FHWA provides National Highway Performance Program funds to state DOTs, state DOTs have significant flexibility in how they distribute these funds among eligible projects. State DOTs generally select and

[11]The National Highway Performance Program is also the most well-funded federal-aid highway program. Its authorized funding for a fiscal year is typically over half of the total authorized funding for the overarching federal-aid highway program for the fiscal year.

prioritize which projects—including pavement projects—will receive federal-aid highway program funding.[12]

Pavement Condition Performance Measures

The Moving Ahead for Progress in the 21st Century Act (MAP-21), enacted in 2012, adopted a performance-based approach for the federal government's surface transportation programs.[13] For the National Highway Performance Program, MAP-21 required that DOT establish performance measures for states to use to assess the condition of National Highway System bridges and pavements within their state. In 2017, FHWA issued a final rule establishing four performance measures for assessing pavement condition.[14] These performance measures are:

1. Percentage of Interstate System pavements in good condition
2. Percentage of Interstate System pavements in poor condition
3. Percentage of non-Interstate National Highway System pavements in good condition
4. Percentage of non-Interstate National Highway System pavements in poor condition.[15]

Pavement Condition Metrics

To assess pavement condition using these performance measures, state DOTs use metrics established by FHWA to classify the overall condition of individual pavement sections on the National Highway System as good, fair, or poor.[16] These metrics are the percent of cracking, the average depth of rutting or the average height of faulting (depending on

[12]*See* 23 U.S.C. § 145. See also appendix IV for more information on state DOTs' general processes for selecting and prioritizing projects for federal-aid highway program funds.

[13]Pub L. No. 112-141, § 1203(a), 126 Stat. 405, 524 (2012) (codified as amended at 23 U.S.C. § 150). MAP-21 also set national goals to be the focus of the federal-aid highway program, one of which is maintaining highway infrastructure, including pavement, in a state of good repair.

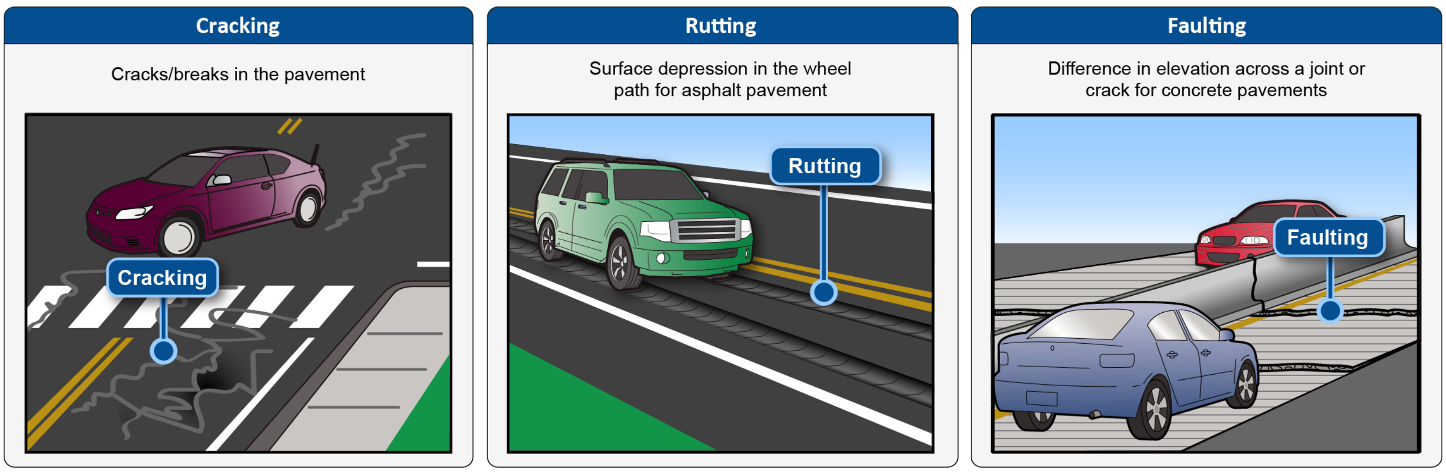
[14]National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program, 82 Fed. Reg. 5886, 5887 (Jan. 18, 2017).

[15]These pavement condition performance measures apply to mainline highways on the National Highway System. 23 C.F.R. §§ 490.303, 490.307(a). Mainline highways are generally defined as the through travel lanes of any highway and do not include ramps, shoulders, turn lanes, crossovers, rest areas, and other pavement surfaces that are not part of the roadway normally traveled by through traffic. *Id*. § 490.101.

[16]This process is described in 23 U.S.C. §§ 490.307(b), 490.311, 490.313.

pavement material), and the International Roughness Index score.[17] See figure 3 for examples of cracking, rutting, and faulting. Based on reported data, pavement sections receive a rating of good, fair, or poor for each metric, according to regulatory criteria. These metric ratings are then collectively used to classify the pavement section's overall condition as good, fair, or poor.

Figure 3: Examples of cracking, rutting, and faulting in pavement



Source: GAO. | GAO-22-104578

A pavement segment with good ratings for all metrics—cracking percent, rutting/faulting (where applicable), and the International Roughness Index—is classified as in good condition. A pavement segment with a poor rating on two or more metrics is classified as in poor condition. A pavement segment that does not meet the criteria to be classified as in good or poor condition is classified as in fair condition. For example, a pavement segment with a good rating on cracking percent but fair ratings on rutting and the International Roughness Index, would be classified as in fair condition. For 2019, FHWA did not use rutting/faulting and cracking metrics and solely used the International Roughness Index metric to classify the condition of pavement on non-Interstate National Highway

[17]A crack is a fissure or discontinuity of the pavement surface; a rut is a surface depression in the wheel path; a fault is a difference in elevation across a joint or crack. The International Roughness Index measures whether travelers experience a rough or a smooth ride while driving on a road. The index is a quantitative measure of a vehicle's up-and-down movement while traveling.

System roads.[18] See figure 4 for examples of pavement classified as good, fair, and poor condition.

Figure 4: Illustrative Examples of National Highway System Pavement Sections in "Good," "Fair," and "Poor" Condition, as Categorized by the Federal Highway Administration

Source: Federal Highway Administration. | GAO-22-104578

Note: FHWA categorizes pavement condition as good, fair, or poor, based on various metrics, including the extent to which the pavement surface has cracks, ruts, or faults.

Reporting of Pavement Condition Data and Targets

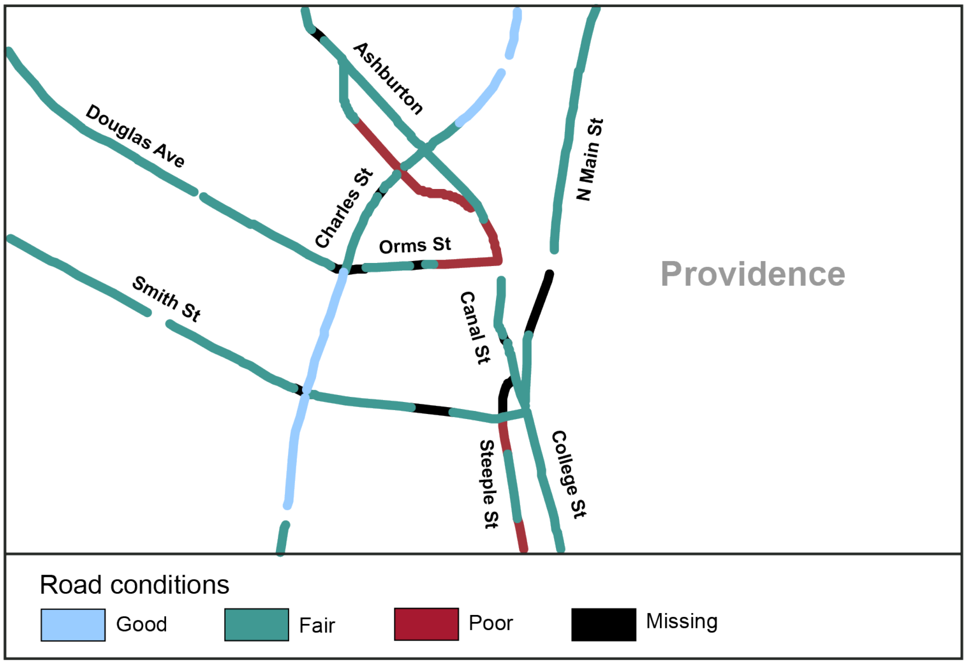
FHWA requires that state DOTs collect pavement condition metrics for the Interstate System annually and collect metrics for the rest of the National Highway System every 2 years.[19] FHWA requires state DOTs to submit these metric data for the National Highway System into the Highway Performance Monitoring System (HPMS)—a national highway information system hosted by FHWA. States report the metric data for a highway in increments of 1/10th of a mile, which allows the data to capture variations in the highway's condition (see figure 5 for an example). FHWA aggregates the data submitted by states and annually

[18]To give state DOTs time to begin collecting all metric data for the National Highway System, FHWA established a time period during which the overall condition for all pavement types could be based on the International Roughness Index rating only. This time period ended December 31, 2017, for Interstate highways and December 31, 2019, for the non-Interstate national highways.

[19]Recognizing that collecting data on pavement metrics other than the International Roughness Index score may be new to some state DOTs, FHWA delayed the requirement to collect data on all of the metrics until January 1, 2018, for the Interstate System and January 1, 2020, for the non-Interstate National Highway System.

calculates the percent of lane miles on the National Highway System in good or poor condition nationwide.[20]

Figure 5: Example of Pavement Condition for Selected Roads on the National Highway System in Providence, Rhode Island, 2019



Source: GAO analysis of Federal Highway Administration pavement condition data. | GAO-22-104578

Note: Data for 2019 was the most recent full year of available data at the time of our analysis.

State DOTs are also required to establish 2- and 4-year performance targets (most recently for 2019 and 2021, respectively) for the pavement condition performance measures.[21] The targets established by state DOTs vary. For example, Kansas DOT has a 4-year target that 55 percent of its non-Interstate National Highway System be in good

[20]Lane miles are the length of a given segment of the National Highway System multiplied by the number of lanes.

[21]FHWA's regulations governing state DOTs' establishing and reporting on their performance targets are located in 23 C.F.R. Part 490, Subpart A. The 2- and 4-year performance targets must reflect the anticipated condition of pavements at the corresponding midpoint and end of each 4-year performance period. However, for the first performance period only, state DOTs are not required to report 2-year performance targets for the performance measures for Interstate System pavement condition. The first performance period lasted from January 1, 2018, to December 31, 2021, and state DOTs must submit their first full performance period progress report by October 1, 2022.

condition, and Maine DOT has a 4-year target that 34 percent of its non-Interstate National Highway System be in good condition.

State DOTs must submit a report to FHWA every 2 years describing the condition of Interstate System and non-Interstate National Highway System pavement, as well as their progress towards achieving their targets. Based on these reports and HPMS data, FHWA will determine whether a state DOT has made significant progress towards achieving its targets at the midpoint and end of each performance period. If FHWA determines that a state DOT has not made significant progress towards achieving a target, then the state DOT must provide a description of planned actions to achieve the target.

Although MAP-21 did not authorize FHWA to approve or reject a state DOT's self-set targets, it did require that DOT establish a minimum level for pavement condition on the Interstate System. FHWA generally requires that no more than 5 percent of a state's Interstate System lane miles can be in poor condition.[22] If FHWA determines that a state DOT is not in compliance with this requirement, the state DOT must set aside a certain amount of federal-aid highway program funding each fiscal year to improve its Interstate System pavement condition until it comes into compliance.[23]

[22]For Alaska, FHWA set the minimum level for Interstate System pavement condition at 10 percent. 23 C.F.R. § 490.315. Lane miles are the length of a given segment of the National Highway System multiplied by the number of lanes.

[23]FHWA must make this determination annually for each state using HPMS data. 23 C.F.R. § 490.317.

Pavement Condition Varies but Tends to be Worse in Communities with Higher Percentages of Underserved Racial and Ethnic Populations, Communities with Higher Rates of Family Poverty, and Urban Areas

Much of the National Highway System Pavement is in Good Condition, but There is Wide Variation

Most pavement on the National Highway System is in good or fair condition, but there is wide variation across and within states, as well as between pavement on Interstate and non-Interstate National Highway System roads. Specifically, roughly 97.6 percent of the lane miles of the National Highway System included in our analysis have pavement that is in good (47.2 percent) or fair (50.4 percent) condition.[24] Relative to those with good and fair pavement, there are very few lane miles with pavement in poor condition (2.4 percent). However, pavement condition is more likely to be worse in urban areas, and in census tracts with higher percentages of underserved racial and ethnic populations or higher family poverty rates. Stakeholders we interviewed and transportation researchers have identified a number of benefits of good pavement

[24]We report pavement condition in terms of lane miles for selected descriptive analyses because FHWA requires state DOTs' performance targets to be set as a percentage of lane miles. Our analysis is based on FHWA Performance Measure Rule 2 (PM2) Pavement Metric Data and HPMS data linked to several publicly available data sources (see app. I), while FHWA's reporting is based on PM2 data. Therefore, the results of our analyses may differ from those reported by FHWA. PM2 refers to data created from pavement metric information submitted by state DOTs in response to FHWA's final rule establishing performance measures for assessing pavement condition. 82 Fed. Reg. 5886, 5887 (Jan. 18, 2017). It also includes pavement condition information.

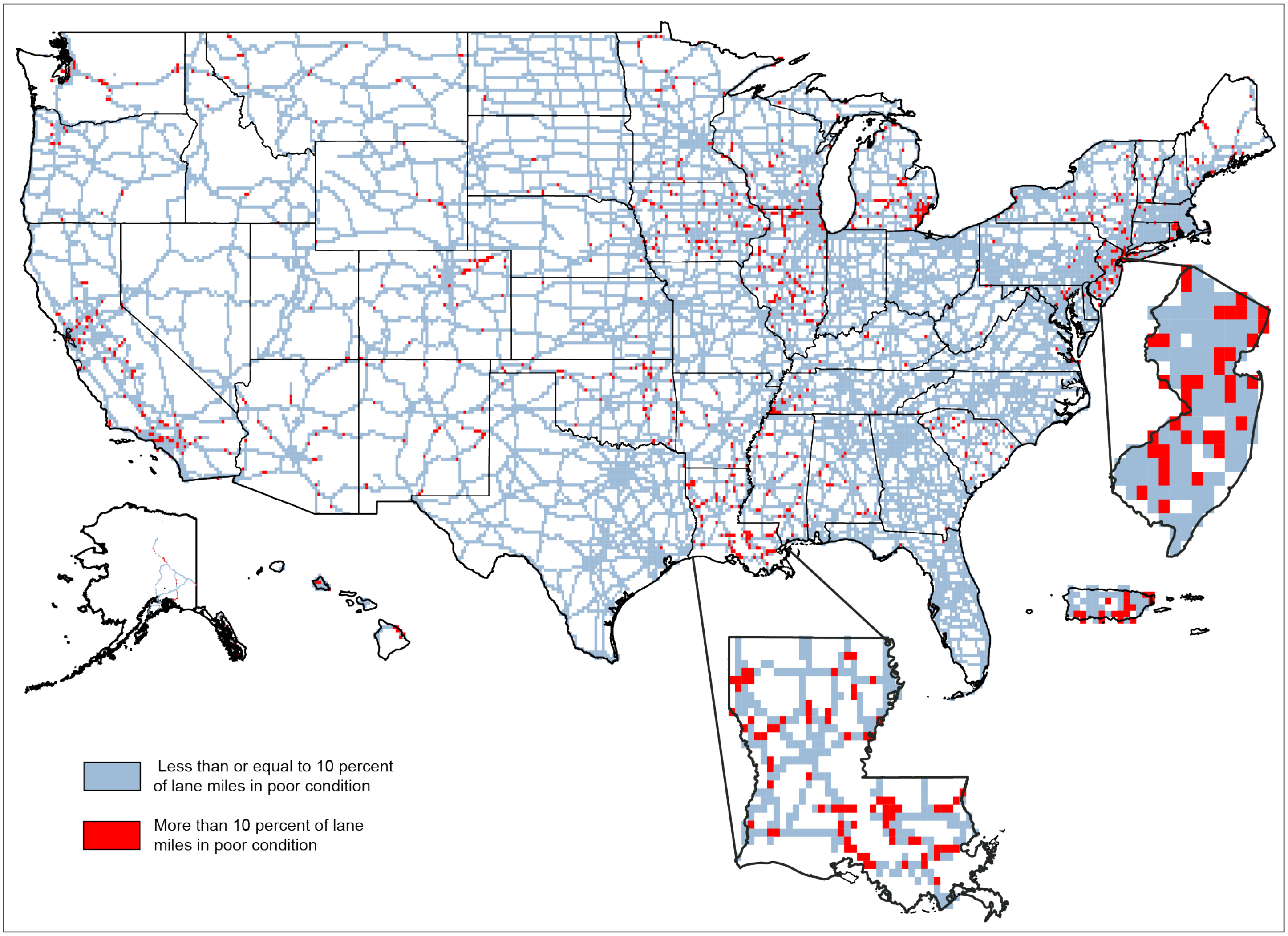
condition, including that it allows for safer and more efficient travel than pavement in other conditions.

Variation by State

Our analysis found that National Highway System pavement condition varies widely by state. For example, 72.3 percent of lane miles in Nevada have pavement in good condition, compared with 18.8 percent of Louisiana's. Similarly, 15.1 percent of lane miles in Rhode Island have pavement in poor condition, compared with 0.2 percent in North Dakota. See table 8 in appendix III for the percentage of lane miles with pavement in good and poor condition on the National Highway System in all states.

Our analysis also found that there are some areas with high concentrations of poor pavement within states on the National Highway System. For example, these concentrations appear in parts of California, Louisiana, New Jersey, and Michigan. See figure 6.

Figure 6: Areas with High Concentrations of Pavement in Poor Condition on National Highway System Lane Miles, 2019

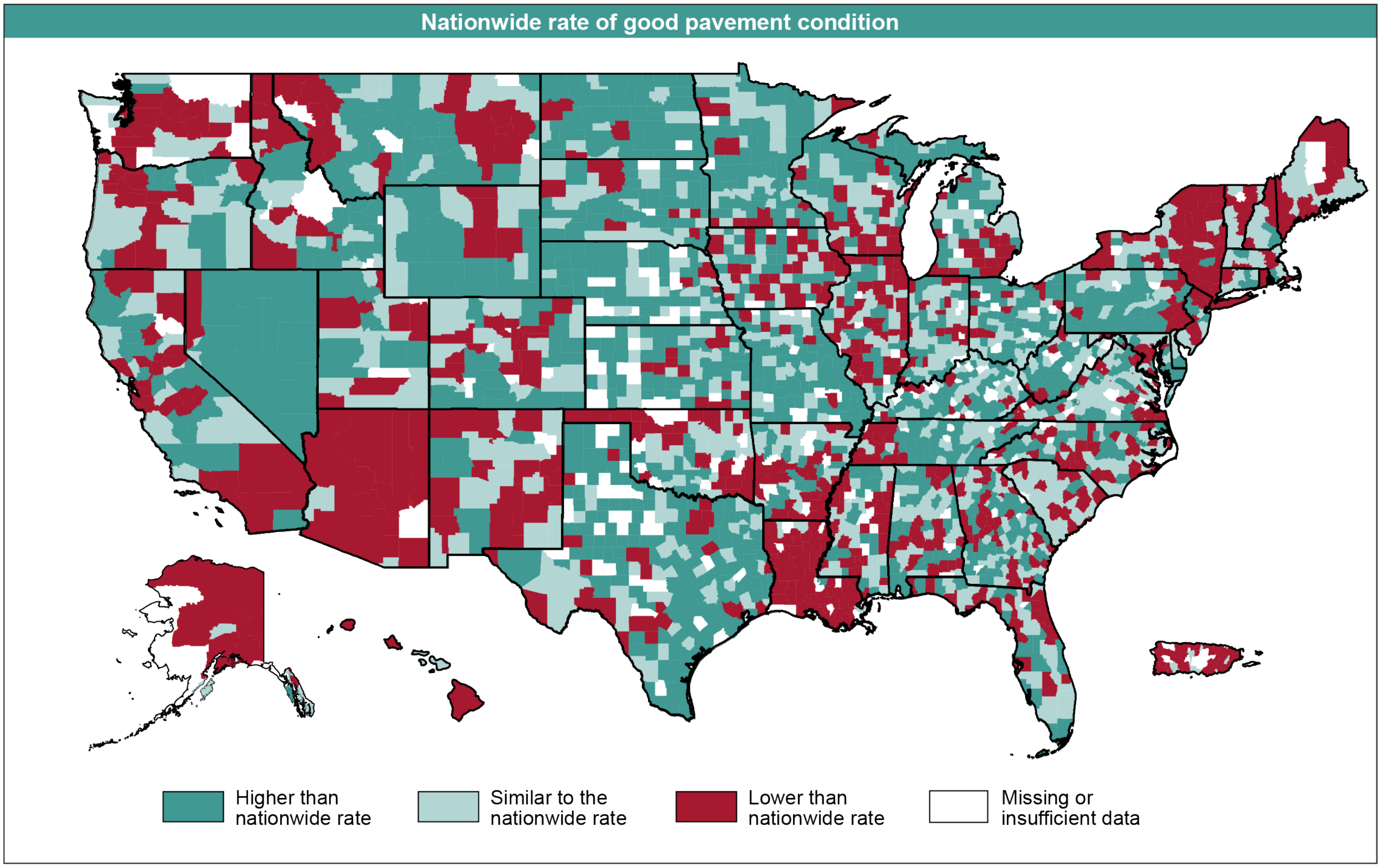


Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

Note: This figure shows the areas where more than one in every ten National Highway System lane miles are in poor condition. Areas were identified from a U.S. grid cell file with 8-mile-by-8-mile grids created using the U.S. county census file. Grid cells with fewer than 10 FHWA Performance Measure Rule 2 (PM2) Pavement Metric Data road segments were not analyzed. Data for 2019 were the most recent full year of available data at the time of our analysis.

In addition, we found variation across counties with respect to pavement condition, when compared to the national average. Specifically, 39.5 percent of counties have a higher rate of good pavement than the nationwide rate. See figure 7.

Figure 7: County Rates of Good Pavement Condition on the National Highway System Compared to the Nationwide Rate, 2019

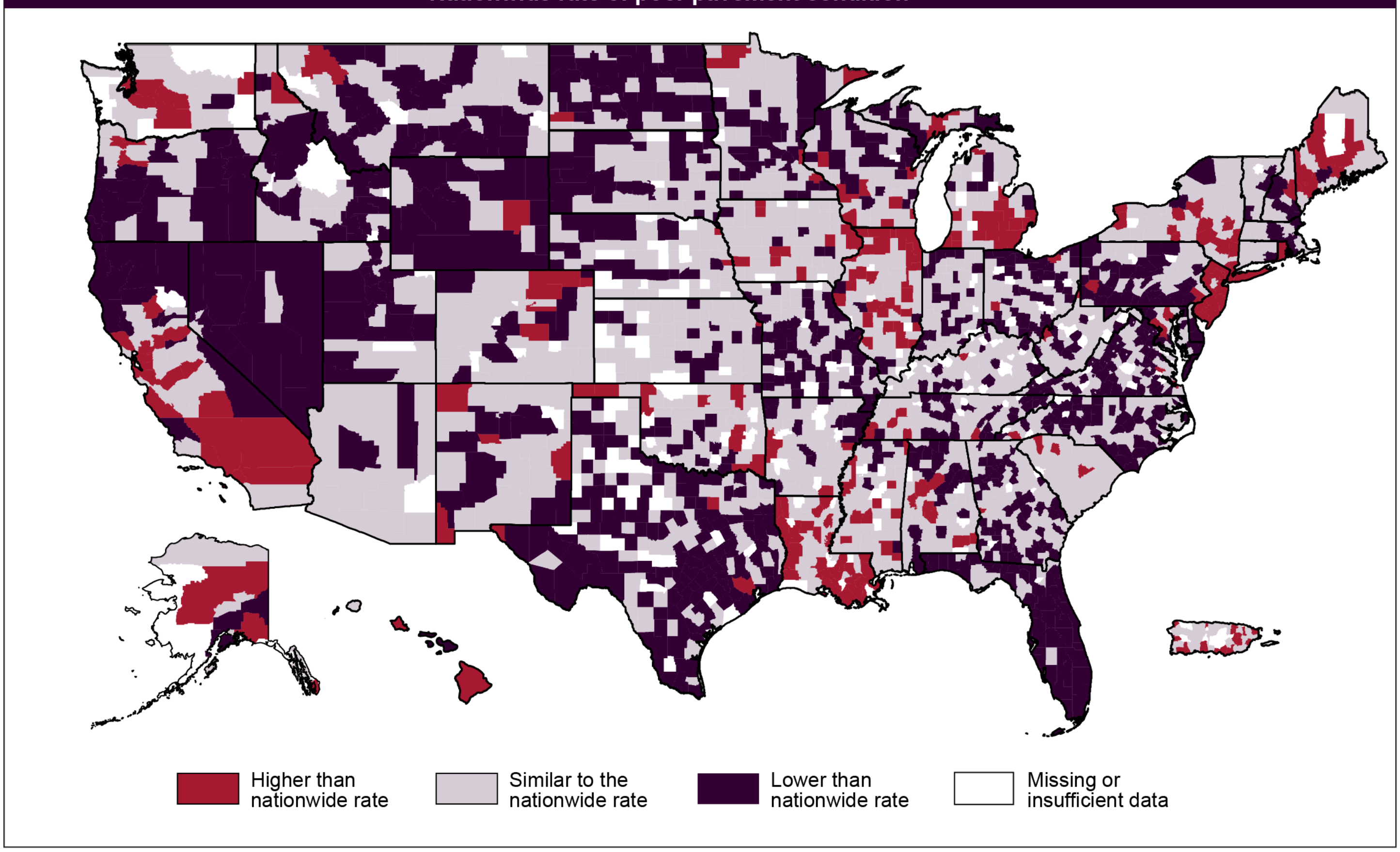


Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

Note: To show the distribution of National Highway System pavement in good condition, we developed a probability map at the county level. We examined the rates of lane miles that have good pavement within an area, relative to the nationwide rates of lane miles with good pavement. Areas marked as “lower than nationwide rate” have a lower proportion of their total lane miles of pavement that are in good condition when compared to the nationwide proportion of total lane miles in good condition. Differences between county and nationwide rates are statistically significant at the 95 percent confidence level. We include counties with at least 30 National Highway System road segments and at least 2 lane miles. Counties that do not meet these criteria appear in white on the map. See appendix I for more details. Data for 2019 were the most recent full year of available data at the time of our analysis.

Conversely, 11 percent of counties have a higher rate of poor pavement condition, when compared to the nationwide rate. See figure 8.

Figure 8: County Rates of Poor Pavement Condition on the National Highway System Compared to the Nationwide Rate, 2019



Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

Note: To show the distribution of National Highway System pavement in poor condition, we developed a probability map at the county level. We examined the rates of lane miles that have poor pavement within an area, relative to the nationwide rates of lane miles with poor pavement. Areas marked as "lower than nationwide rate" have a lower proportion of their total lane miles of pavement that are in poor condition when compared to the nationwide proportion of total lane miles in poor condition. Differences between county and nationwide rates are statistically significant at the 95 percent confidence level. We include counties with at least 30 National Highway System road segments and at least 2 lane miles. Counties that do not meet these criteria appear in white on the map. See appendix I for more details. Data for 2019 were the most recent full year of available data at the time of our analysis.

Variation by Interstate System versus Non-Interstate National Highway System

We found that Interstate System roads are generally in better condition than non-Interstate National Highway System roads. Specifically, our analysis found that 61 percent of pavement on Interstate System lane miles is in good condition compared with 41 percent of pavement on non-Interstate National Highway System lane miles. One percent of Interstate

System lane miles have pavement in poor condition compared with 3 percent of non-Interstate National Highway System lane miles.[25] The amount of good pavement on Interstate System lane miles varies by state. For example, 80.6 percent of Interstate System lane miles in West Virginia have good pavement condition compared with 26.1 percent in Maine. This variation also exists for good pavement on non-Interstate National Highway System lane miles. For example, 61.6 percent of pavement on non-Interstate National Highway System lane miles in Missouri have good pavement condition compared with 13.2 percent in New York. See table 8 in appendix III for the percentage of Interstate and non-Interstate National Highway System lane miles with pavement in good and poor condition for all states.

Variation by Percentage of Underserved Racial and Ethnic Populations

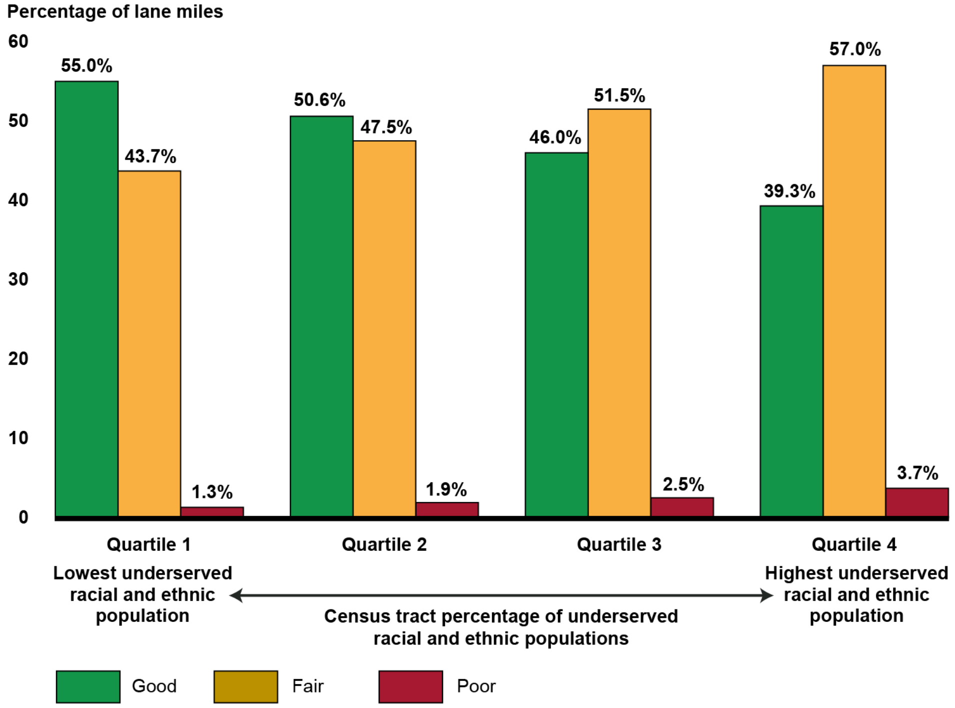
Within states, pavement condition also varies across communities. Our analysis showed that census tracts with the highest percentages of underserved racial and ethnic populations have the lowest percentages of National Highway System pavement in good condition. These census tracts also have nearly three times the amount of pavement in poor condition compared to census tracts with the lowest percentages of underserved racial and ethnic populations.[26] Specifically, 3.7 percent of pavement in census tracts with the highest underserved ethnic and racial populations are in poor condition, compared to 1.3 percent of pavement in census tracts with the lowest underserved racial and ethnic populations. See figure 9.[27]

[25]As previously mentioned, FHWA may not approve or reject state DOTs' self-set targets for pavement condition. However, FHWA requires that state DOTs maintain their Interstate System pavement condition so that no more than 5 percent of Interstate System lane miles within their state are in poor condition.

[26]For the purposes of this report, we measured race and ethnicity as the percentage of the population in a census tract that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino, which we refer to collectively as underserved racial and ethnic populations.

[27]The statistics presented in this section and in figures 9, 10, and 11 are descriptive. In this analysis, we have not controlled for community characteristics or factors that our literature review and stakeholders identified as affecting pavement condition, such as climate and traffic. In the next section, we show the results of a statistical model that does control for climate and traffic.

Figure 9: Pavement Condition Variation on the National Highway System by Census Tract Percentage of Underserved Racial and Ethnic Populations (by Quartile), 2019



Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

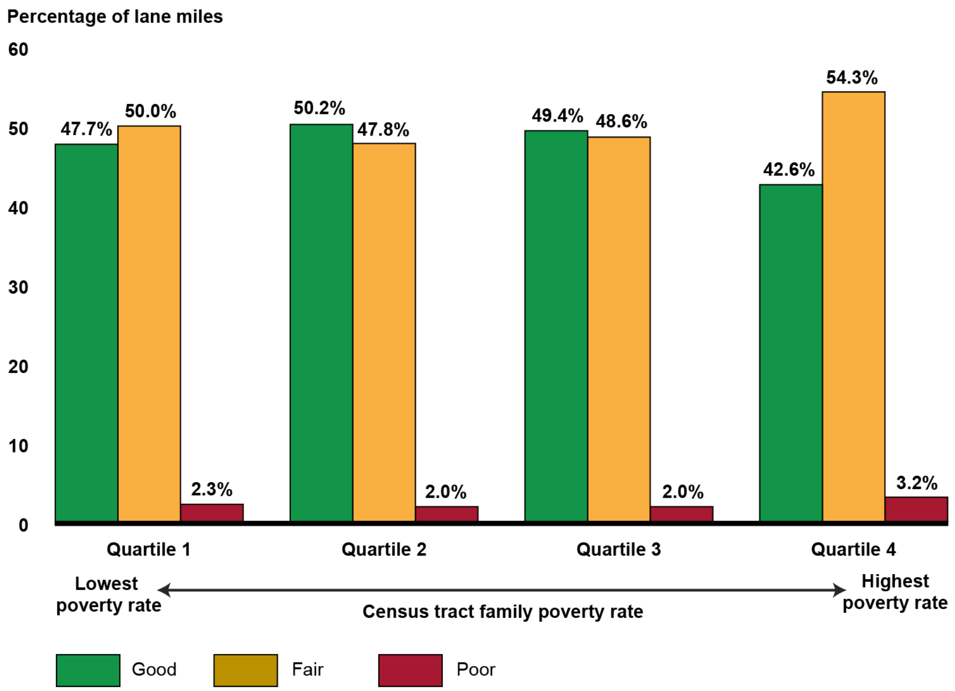
Note: The first set of bars represents the census tracts with the smallest percentage of underserved racial and ethnic populations, and the fourth set of bars represents census tracts with the largest percentage of underserved racial and ethnic populations. Data for 2019 were the most recent full year of available data at the time of our analysis.

Variation by Family Poverty Rates

Our analysis also showed that census tracts with the highest rates of family poverty also have the highest percentage of National Highway System pavement in poor condition, and the lowest percentage in good condition.[28] Specifically, 3.2 percent of pavement in census tracts with the highest family poverty rate are in poor condition, while census tracts with the lowest family poverty rates have less than 2.5 percent of pavement in poor condition. See figure 10.

[28]We defined family poverty rate as the percentage of families in a census tract that have an income below the poverty level using data from the U.S. Census Bureau's American Community Survey. The Census Bureau uses a set of income thresholds that vary by family size and composition to determine who is in poverty.

Figure 10: Pavement Condition Variation on the National Highway System by Census Tract Family Poverty Rate (by Quartile), 2019



Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

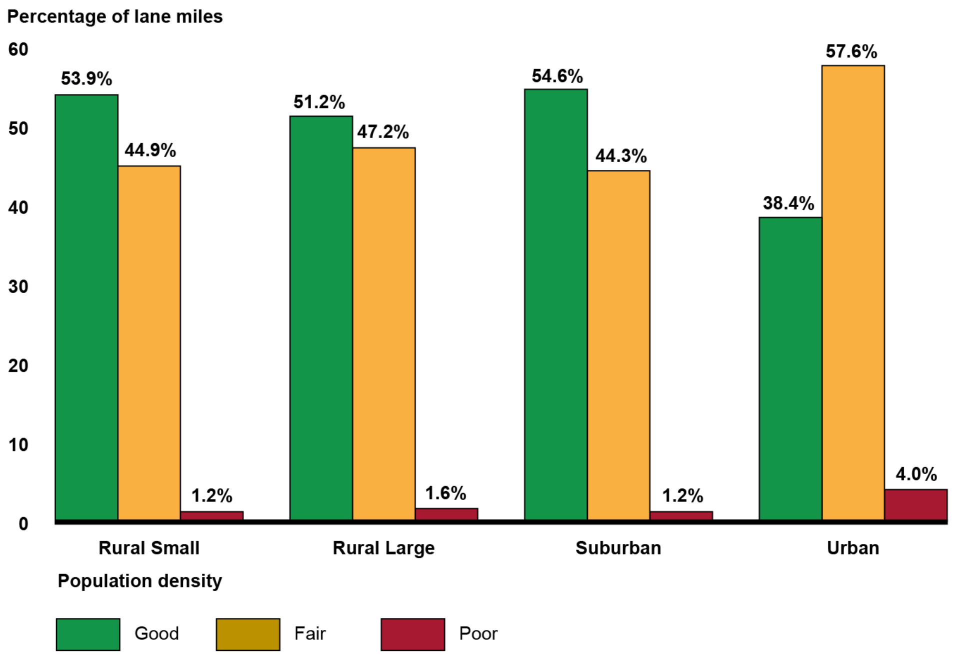
Note: Data for 2019 were the most recent full year of available data at the time of our analysis.

Variation by Urban, Suburban, and Rural Areas

We also found that urban areas have worse pavement than suburban, rural large town, or rural small town areas.[29] Urban areas have the lowest percentage of National Highway System pavement in good condition and the highest percentages of pavement in fair and poor condition. Specifically, 4 percent of pavement on urban area roads is in poor condition compared with 1.2 percent of suburban and rural small town roads. See figure 11.

[29]For the purposes of this report, we use population density to indicate whether a census tract is an urban core, suburban, rural large town, or rural small town area according to USDA's 2010 Rural-Urban Commuting Area classification.

Figure 11: Pavement Condition Variation on the National Highway System by Census Tract Population Density Category, 2019



Source: GAO analysis of Federal Highway Administration and U.S. Department of Agriculture data. | GAO-22-104578

Note: Data for 2019 were the most recent full year of available data at the time of our analysis.

The statistics presented above are descriptive, and have been presented without controlling for other community characteristics or other factors that our literature review and stakeholders identified as affecting pavement condition, such as climate and traffic density. The next section presents our results when controlling for such factors.

Pavement Condition Is More Likely to be Worse in Communities with Higher Percentages of Underserved Racial and Ethnic Populations, Communities with Higher Rates of Family Poverty, and Urban Areas

Descriptive statistics, as shown above, do not control for factors that may affect pavement condition, such as climate and traffic density. To account for this, we conducted additional analyses and found that, even when controlling for certain factors, a census tract's racial and ethnic population, family poverty rate, and population density were associated with its likelihood of having good pavement. Specifically, to better understand and isolate the relationships between these community characteristics and pavement condition, we developed a statistical model to control for factors such as climate and traffic density.[30]

We found pavement is less likely to be in good condition for communities where there are higher rates of underserved racial and ethnic populations or family poverty, and for urban areas.[31] Specifically, these characteristics are all individually associated with a lower likelihood of having pavement in good condition.[32] For example, pavement on roads in census tracts with higher rates of underserved racial and ethnic populations has a lower likelihood of being in good condition, even when controlling for traffic density and other factors.[33] Additionally, pavement on roads in urban areas is associated with a lower likelihood of being in good condition compared to pavement in suburban, rural large town, and rural small town areas. These results are consistent for pavement on both Interstate System and non-Interstate National Highway System roads.

The probability of pavement being in good condition is lower for roads in census tracts with higher rates of underserved racial and ethnic populations, even after accounting for other factors, such as climate and traffic density. See figure 12. For example, for two hypothetical urban census tracts that have the same climate, traffic density, and family poverty rate:

[30]We incorporated other variables that might be related to road condition, such as climate and traffic, in order to control for known variations in pavement condition. To identify the variables of interest, we conducted a literature review, spoke with agency and DOT officials in selected states, and reviewed available data. See appendix I, table 2 for a list of all of the variables we controlled for in our model.

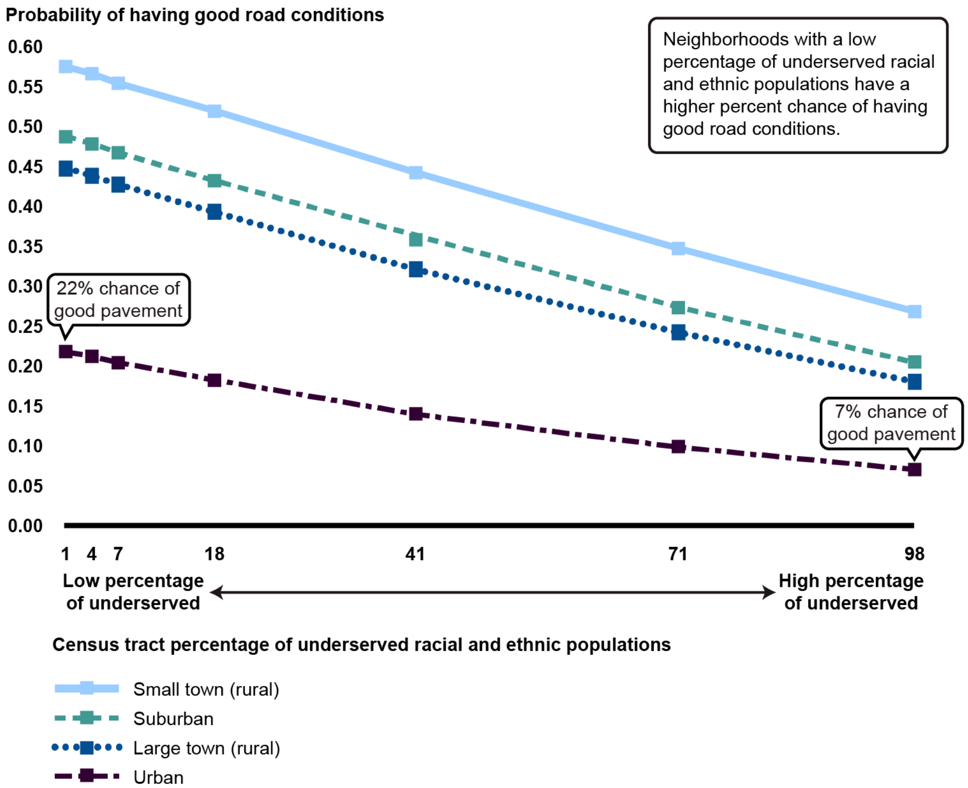
[31]The results from the statistical model are associational and do not imply causation between community characteristics and pavement condition. Please see appendix I for more information and considerations for the statistical model.

[32]By individually we mean that each of the three community characteristics are associated with a lower likelihood of having pavement in good condition when holding all other factors in the model constant, including the two other community characteristics. Due to the small number of roads with poor pavement condition, we could not run a statistical model determining the likelihood of having poor pavement condition based on these characteristics. There were sufficient data to run our model to determine the likelihood of having good pavement condition based on these characteristics.

[33]We use road segments as our definition of a road within this engagement, unless otherwise noted. Segments are units within the PM2 data, and segment lengths are generally 1/10th of a mile. See appendix I for more details.

- Pavement on a road in the census tract with an almost fully underserved racial and ethnic population has a 7 percent chance of being in good condition.
- Pavement on a road in the census tract with an almost fully White, non-Hispanic or Latino population has a 22 percent chance of being in good condition.

Figure 12: Probability of Pavement in Good Condition on the National Highway System by Underserved Racial and Ethnic Population Rate and Population Density Category, 2019



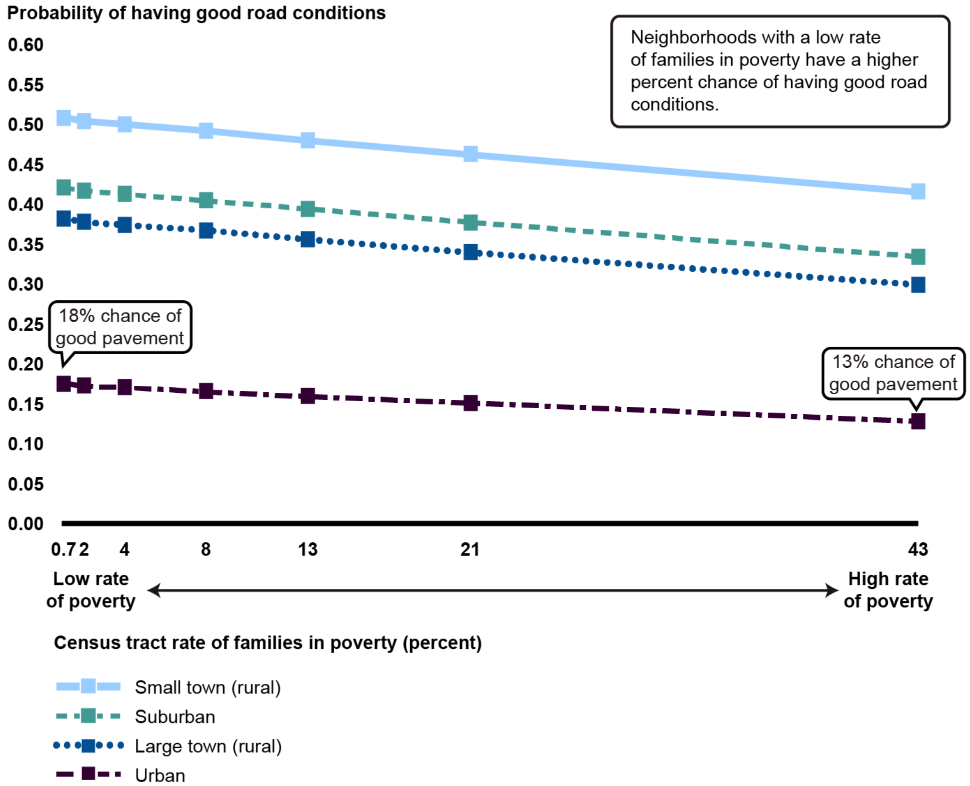
Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Note: In this figure, we controlled for poverty rate, underserved racial and ethnic population, population density, traffic density, climate/weather, and whether a road is on the Interstate System. Probabilities are based on our regression model that evaluated an otherwise typical census tract, but where the census tract percent of underserved populations (represented by the percent of the population that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino) varied according to the 1st, 10th, 25th, 50th, 75th, 90th, and 99th percentiles of the distribution in our sample, as displayed along the x-axis. We define a census tract as otherwise typical in that it has the sample average for other variables in the model that are not part of this figure, such as percentage of families in poverty and traffic. The 95 percent confidence intervals for our estimates from our model indicate that probabilities are significantly different across population densities except for those between suburban and large town rural at the highest level of underserved racial and ethnic populations. Generally, 95% confidence intervals for American Community Survey estimates used as data in this model are within +/-15%. Data for 2019 were the most recent full year of available data at the time of our analysis.

The probability of pavement being in good condition is also lower for roads in census tracts with higher family poverty rates. See figure 13. For example, for two hypothetical urban census tracts that are the same in terms of climate, traffic density, and underserved racial and ethnic population:

- Pavement on a road in the census tract with nearly half of its families in poverty has a 13 percent chance of being in good condition.
- Pavement on a road in the census tract with almost none of its families in poverty has an 18 percent chance of being in good condition.

Figure 13: Probability of Pavement in Good Condition on the National Highway System by Family Poverty Rate and Population Density Category, 2019



Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Note: In this figure, we controlled for family poverty rate, underserved racial and ethnic population, population density, traffic density, climate/weather, and whether a road is on the Interstate System. Probabilities are based on our regression model that evaluated an otherwise typical census tract, but where the census tract percent of families in poverty, varied according to the 1st, 10th, 25th, 50th, 75th, 90th, and 99th percentiles of the distribution in our sample, as displayed along the x-axis. We define a census tract as otherwise typical in that it has the sample average for other variables in the model that are not part of this figure, such as percentage of underserved racial and ethnic population (which was represented by the percent of the population that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino). The 95 percent confidence intervals for our estimates from our model indicate that probabilities are significantly different across population densities except for those between suburban and large town at the highest rate of families in poverty. Generally, 95% confidence intervals for American Community Survey estimates used as data in this model are within +/-15%. Data for 2019 were the most recent full year of available data at the time of our analysis.

Like any quantitative model, our estimates are subject to certain limitations. Our results examine associations between community characteristics and pavement condition and do not imply causation. In addition, this model is just one example examining associations between selected community characteristics and pavement condition. We selected community characteristics that were themselves key measures of inequality and that correlated with other measures of inequality, such as percentage of the population with vehicle access. However, other measures of inequality may have different associations with pavement condition than those we describe here.[34] Further, while we accounted for climate and traffic, which are known to be associated with pavement condition in the academic literature and from our interviews with state DOT officials, there were other factors, such as soil type, that we were unable to include in our model.[35] The findings from our model are a proof of concept that it is possible to examine associations between community characteristics and pavement condition. For more information on the quantitative model, see appendix I.

FHWA Does Not Regularly Examine Pavement Condition within States, Which Limits Its Ability to Identify Risks to Its Strategic Goals

FHWA analyzes statewide pavement condition, but does not regularly examine pavement condition data within states, such as at the local level. DOT and FHWA both have strategic goals and objectives related to safe, reliable, and efficient transportation, and DOT's fiscal year 2022-2026 strategic plan also contains a new strategic goal to ensure that "equity considerations for disadvantaged and underserved communities are integrated into the planning, development, and implementation of all transportation investments."[36] *Standards for Internal Control in the Federal Government* states that management should identify the information needed to achieve its objectives and address any risks.[37] With regard to pavement condition, such information could include the results from additional analyses of pavement condition data to identify risks to FHWA and DOT's goals for safe, reliable, efficient, and equitable

[34]As discussed in appendix I, another measure we considered including in our model was the publicly available 2018 Social Vulnerability Index (SVI) from the Centers for Disease Control and Prevention (CDC). Because we did not include this measure, we do not know its association with the likelihood of having good pavement condition.

[35]FHWA officials expressed concern regarding the accuracy of soil data, and we did not include the data in our analyses. In addition, we were unable to control for other factors, including state use and sources of funding for projects on and ownership of National Highway System roads, due to a lack of data. An area for further research would be to examine these factors and their association, if any, with pavement condition.

[36]FHWA has not released a new strategic plan, but its fiscal year 2019–2022 strategic plan adopted DOT's safety and infrastructure strategic goals as part of its own strategic plan.

[37]GAO-14-704G.

transportation. DOT has also recognized the importance of data in achieving its goals. For example, DOT's strategic plan includes "strengthening the collection, analysis, sharing, and use of equity data" as a strategy to achieve its equity goal.[38] The strategic plan also notes that DOT intends to conduct technical assistance activities to help revitalize communities by improving the built environment and to support state and local efforts to include the measurement of equity impacts in transportation planning.[39]

FHWA has taken steps to analyze and report on pavement conditions at the state level. FHWA uses the pavement condition data submitted by state DOTs to calculate the percent of National Highway System roads in good and poor condition for each state and compares these calculations against state DOTs' self-set targets. FHWA has noted that requiring state DOTs to set pavement condition targets and report on their progress facilitates FHWA's review of the effectiveness of the federal-aid highway program as a means to address surface transportation performance at a national level.[40] In addition, FHWA developed national and state pavement condition dashboards. The state dashboards display each state DOT's pavement condition targets and the percent of pavement in good and poor condition for Interstate and non-Interstate National Highway System roads, by year. The national dashboard provides information on the percent of pavement in good and poor condition for Interstate roads. FHWA has also used pavement condition data to report on its own annual performance goals (most recently in 2019), including the percent of Interstate pavement in good or fair condition, and the percent of vehicle miles traveled on National Highway System pavements in good condition.

However, FHWA officials told us they do not regularly use pavement condition data submitted by state DOTs to analyze the pavement condition of geographic areas within states, such as localities or census tracts. FHWA officials told us they generally do not do this analysis because FHWA only uses the pavement condition data it collects from

[38]The strategic plan noted that its operating administrations, such as FHWA, would be some of the lead agencies to implement this strategy.

[39]FHWA also has a variety of programs that provide technical assistance to state DOTs as well as local agencies.

[40]National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program, 82 Fed. Reg. 5886, 5887 (Jan. 18, 2017).

state DOTs through the National Highway Performance Program for the purposes set forth in the statute and regulations implementing the program.[41] These purposes include ensuring that state DOTs have made significant progress towards their pavement condition performance targets and are complying with minimum pavement condition requirements for the Interstate System. While FHWA officials gave an example of one case in which they did inquire with a state DOT after noticing clusters of pavement in poor condition in the state DOT's data, they noted that such activities are ad hoc and were conducted under their broad research, development, and technology deployment authority.[42]

As noted above, our more granular analysis of pavement condition data within states identified geographic areas with concentrations of poor pavement within states. We also found that urban areas and areas with higher levels of underserved racial and ethnic populations or higher family poverty rates are less likely to have pavement in good condition. When discussing our analysis of pavement condition within states with DOT and FHWA officials in February 2022, they told us that although they have not undertaken this type of analyses of pavement condition, there are ongoing efforts related to enhancing the equity of DOT programs. For instance, in response to Executive Order 13985, DOT issued a request for information asking for public input on what data, tools, and methods could assist DOT in assessing transportation equity, including whether its programs and policies perpetuate systemic barriers to opportunities and

[41]*See* 23 U.S.C. §§ 119, 150; 23 C.F.R. Part 490.

[42]FHWA has broad authority to conduct research, development, and technology deployment activities related to the performance of the nation's highways and other surface transportation infrastructure. 23 U.S.C. §§ 502, 503; 49 C.F.R. § 1.85. FHWA did not identify any legal prohibition on using the data it already collects from state DOTs and publically available external sources for additional research purposes under these authorities.

benefits for underserved communities.[43] In addition, DOT officials stated that in response to another executive order, DOT is in the process of developing assessment tools that could be used evaluate potential equity impacts of its discretionary grant programs on disadvantaged communities.[44] However, officials told us that while these efforts could be applied across all DOT programs, they are not specifically targeted at pavement condition. Thus, as of June 2022, FHWA has not identified what pavement-specific analyses it will conduct, if any.

While statute allows state DOTs' self-set performance targets for pavement condition to vary, concentrations of poor pavement conditions and differences in pavement condition by community characteristics could pose risks to FHWA and DOT meeting their strategic goals related to safe, reliable, efficient, and equitable transportation. Of the 19 state and local transportation stakeholders we interviewed, 16 noted that pavement in good condition is safer or more efficient for travel than pavement in other conditions. For example, officials from two state DOTs noted that rain collects in pavement with ruts, which increases the risk of hydroplaning. Officials from four state DOTs stated that pavement in good

[43]Executive Order 13985, issued in January 2021, generally directs federal agencies to assess whether members of underserved communities face systemic barriers in accessing benefits and opportunities available under the agencies' policies and programs and whether agency action may be necessary to advance equity in their programs. Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, Exec. Order No. 13985, § 5 (Jan. 20, 2021). The executive order defines equity as, "the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality." Request for Information on Transportation Equity Data, 86 Fed. Reg. 28,189 (May 25, 2021).

[44]Specifically, DOT officials noted that this work was being done in response to Executive Order 14008, which generally directs federal agencies to make economic and environmental justice part of their missions by developing programs, policies, and activities to address the inequitable, adverse impacts on disadvantaged communities that have been historically marginalized as well as overburdened by pollution and underinvestment in transportation and other infrastructure. It also created the Justice40 Initiative, which has a goal that 40 percent of the overall benefits of certain federal investments, including transportation, flow to disadvantaged communities. Tackling the Climate Crisis at Home and Abroad, Exec. Order No. 14008, §§ 219, 223 (Jan. 27, 2021).

condition is also safer for motorcyclists and bicyclists. In addition, studies have found links between pavement condition and traffic safety.[45]

Because FHWA has generally not analyzed pavement condition within states, such as at the local level, it lacks awareness of pavement issues that could pose risks to its strategic goals, such as concentrations of poor pavement condition within a state or differences that disproportionately affect underserved communities. Specifically, while FHWA requires that states have no more than 5 percent of Interstate System lane miles in poor condition, analyzing the pavement data at a more granular level could identify whether pavement in poor condition is concentrated in certain communities. For example, we identified clusters of poor pavement condition within states (see figure 6), but nearly all states did not exceed the 5 percent limit on poor pavement condition for Interstate System roads in 2019. As previously noted, we were not able to control for all variables that could affect pavement condition, and we reviewed data for a single year. Thus, additional analyses of the poor pavement concentrations and the differences by community characteristics or other factors could also help FHWA understand how and why these conditions are occurring, and identify strategies and opportunities to ensure that all communities have equitable pavement conditions.

Such an analysis could also inform FHWA and DOT efforts to implement strategies highlighted in DOT's strategic plan, such as those to provide technical assistance to help states measure equity impacts and "revitalize communities by improving the built environment." Such technical assistance could also help existing state DOT efforts. For example, pavement management officials from four of the six state DOTs we spoke with said that there were discussions underway at their state DOTs to ensure state transportation investments are equitably distributed. Additional analyses of already-available data from the HPMS and other publicly available data by FHWA may help these state DOTs identify and target areas of inequitable pavement condition. This in turn could help DOT and FHWA ensure that they are more fully achieving their strategic goals related to safe, reliable, efficient, and equitable transportation.

[45]Huanghui Zeng, Michael D. Fontaine, Brian L. Smith, "Estimation of the Safety Effect of Pavement Condition on Rural, Two-Lane Highways," *Transportation Research Record: Journal of the Transportation Research Board*, no. 2435 (2014): 45; Yingfeng Li and Jie Huang, "Safety Impact of Pavement Conditions," *Transportation Research Record: Journal of the Transportation Research Board*, no. 2455 (2014): 77; and J. Lee, M. Abdel-Aty. E. Nyame-Baafi, "Investigating the Effects of Pavement Roughness on Freeway Safety using Data from Five States," *Transportation Research Record*, vol. 2674, no. 2 (2020): 127.

Without more granular analysis, DOT and FHWA may continue to focus on aggregated, state-level pavement condition data and strategic goals set at the national level. Such an approach could lead the agencies to overlook concentrations of poor pavement affecting urban communities and communities with higher levels of underserved ethnic and racial populations or higher family poverty rates.

Conclusions

Preservation and maintenance of the approximately 220,000 miles of public roads on the National Highway System are essential to our nation's economy and mobility. In its 2022-2026 strategic plan, DOT included equity, along with safety, reliability, and efficiency in transportation, as its goals to ensure that all roads—regardless of location—are safe and uncongested. However, our analyses of FHWA's pavement condition data found concentrated areas with poor pavement condition. We also found that urban areas as well as areas with higher percentages of underserved racial and ethnic populations or higher family poverty rates are less likely to have pavement in good condition.

DOT and FHWA are in the process of assessing whether there is equitable access to the transportation benefits provided under their policies and programs, and some state DOTs are exploring similar initiatives. We were able to use FHWA's existing data and publicly available census data to identify potential risks to FHWA and DOT's strategic goals of safe, reliable, efficient, and equitable transportation.

Using a similar combination of data, FHWA could conduct analyses of pavement condition within states, such as at the local or census tract level. Such analysis could allow FHWA to identify potential strategies to help states detect and address issues that may be contributing to inequitable pavement conditions. It also could assist state DOTs in meeting their performance targets while helping improve overall pavement condition within the states.

Recommendations for Executive Action

We are making the following two recommendations to FHWA:

The Deputy Administrator of FHWA should analyze pavement condition data, such as Highway Performance Monitoring System data, to examine the concentration of poor pavement in specific areas within states and differences in pavement condition by community or other characteristics, which could include race and ethnicity, poverty, or population density. Such an analysis could also incorporate more recent pavement condition data, control for additional factors that may affect pavement condition, or include statistical modeling of pavement conditions within a state. (Recommendation 1)

Based on the outcome of FHWA's analyses of pavement condition data, the Deputy Administrator of FHWA should identify potential strategies to help states detect and address issues that could contribute to concentrations in poor pavement and differences in pavement condition by community or other characteristics, which could include race and ethnicity, poverty, or population density. (Recommendation 2)

Agency Comments and Our Evaluation

We provided a draft of this report to DOT for review and comment. In its written comments, reproduced in appendix V, DOT partially concurred with the two recommendations. Specifically, DOT noted that FHWA plans to take a number of steps, including improving its administration of the National Highway Performance Program, collecting and analyzing pavement condition data, and advancing its understanding of the historical ramifications of highway investments on communities. Additionally, DOT cited FHWA plans to examine where National Highway Performance Program funds are invested and the contributing factors driving those investment decisions. According to DOT, FHWA will use the results of this analysis to identify potential strategies to help states mitigate investment decision-making processes that may potentially lead to inequitable outcomes.

We believe these actions, if fully implemented, will better position FHWA to examine and help states address inequitable pavement conditions. However, we continue to believe that DOT would benefit from assessing pavement condition within states, which would enhance awareness of issues that could pose risks to its strategic goals, such as concentrations of poor pavement condition or differences across communities. We will continue to monitor FHWA's implementation of its proposed actions to assess the extent to which it addresses the recommendations.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Transportation, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2834 or repkoe@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix VI.

Elizabeth Repko
Director
Physical Infrastructure Issues

Appendix I: Description of the Geospatial and Regression Analysis of Pavement Conditions and Community Characteristics

To describe the distribution of good and poor pavement conditions on the National Highway System (NHS), including the Interstate System, as well as the likelihood of pavement being in good condition when evaluated against certain community characteristics, we conducted a geospatial and regression analysis using data from several sources.

The Federal Highway Administration (FHWA) requires that state departments of transportation (state DOTs) collect pavement condition metric data for the Interstate System annually and for the rest of the National Highway System every 2 years, as required by regulation.[1] FHWA also requires state DOTs submit these metric data for the National Highway System into the Highway Performance Monitoring System—a national highway information system hosted by FHWA. State DOTs report the metric data for a highway in short sections of 1/10th of a mile, which allows the data to capture variations in the highway's condition. Roads can have a varying number of lanes, thus, the data include "lane miles," which are the length of a given segment of the National Highway System multiplied by the number of lanes. These reported metric data are used to classify the overall condition of a pavement section as good, fair, or poor in accordance with FHWA's regulations.

As an overview, to conduct our analysis, we merged several sources of data:

- 2019 Performance Measure Rule 2 (PM2) Pavement Metric Data on road pavement conditions and Highway Performance Monitoring System (HPMS) data on road characteristics, which we obtained from FHWA.[2]
- Publicly available census tract characteristics from Census' 2015-2019 American Community Survey (ACS).
- Publicly available Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) climate data from the National Aeronautics and Space Administration (NASA), downloaded from FHWA.
- Publicly available 2010 Rural-Urban Commuting Area (RUCA) Codes related to population density from the US Department of Agriculture's (USDA) Economic Research Services (ERS).

[1]FHWA's regulations governing the collection, calculation, reporting, and use of pavement condition metric data are primarily located in 23 C.F.R. §§ 490.309, 490.311, 490.313.

[2]Data for 2019 were the most recent full year of available data at the time of our analysis.

Using these sources of data, we examined the spatial distributions of good and poor pavement. We found that some counties have statistically higher rates of good pavement or poor pavement, when compared to the national rate, and these counties are distributed throughout the nation.

We then developed statistical regression models to assess whether community characteristics—which we define as (1) family poverty rate, (2) race and ethnicity, and (3) population density—were associated with the likelihood of pavement being in good condition, when controlling for other community characteristics or other factors identified as affecting pavement condition, such as climate and traffic density.[3] Our results indicate that pavement condition is worse for communities with higher rates of underserved racial and ethnic populations, communities with higher rates of families in poverty, and in urban areas. The details of our analysis are described below.

Methods

To identify the variables of interest, we conducted a literature review, spoke with agency and DOT officials in selected states, and reviewed available data.

Definition of a Road

There are different units of analysis that might be considered when describing a road. Segments are the units within the PM2 data, where segment lengths are generally 1/10th of a mile. We use segments as our definition of a road within this engagement, unless otherwise noted.[4]

SEGMENT_LENGTH is the PM2 field that contains the length of a segment. For all states except for Arizona, this field was provided by FHWA. Lane miles are the length of the road segment multiplied by the

[3]For the purposes of this report, we measured population income by the percentage of families in poverty in a census tract, race and ethnicity by the percentage of the population that is an underserved racial or ethnic group, represented by the percentage of the population that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino, within a census tract, and population density by whether a census tract is an urban core, suburban, rural large town, or rural small town according to USDA's 2010 Rural-Urban Commuting Area classification and the Washington State Department of Health's Guidelines for Using Rural-Urban Classification Systems for Community Health Assessments Scheme 1 classification.

[4]This is because FHWA's regulations define a pavement section as a nominally 0.1 mile-long segment that defines the limits of the pavement metrics it requires state DOTs to submit into HPMS and uses to classify the overall condition of the segment as good, fair, or poor. See 23 C.F.R. § 490.305.

number of lanes. For all states except for Arizona, this information is provided in a ‘Lane_Miles’ field included in the data provided by FHWA.

For Arizona, the number of lane miles was calculated in using inputs from two files:

- Arizona’s PM2 file, which contained ‘End_Point’ and ‘Begin_Point’ fields based on the mile marker where the segment started and ended.
- Arizona’s through lane data file, which contained the ‘NumberofLa’ field indicating the number of lanes corresponding to a specified length of road segment.

Data Linkage

All data provided by FHWA are assigned location information through a process known as dynamic segmentation. In dynamic segmentation, each road segment is defined by a route ID, start point, and length or end point. FHWA indicated that the reference data for dynamically segmented highways is the state All Road Network of Linear Referenced Data (ARNOLD) data. FHWA provided ARNOLD, PM2, and HPMS data files for all states, including Arizona, to GAO.

In all states except for Arizona, the PM2 data file had already been referenced relative to the ARNOLD file in the data provided to GAO. Before HPMS data could be linked to PM2 data, it required linear referencing as well. We used the PM2 data file as the reference data set to complete the linear referencing of the HPMS sections. We then used the intersect tool to identify the individual HPMS section that intersected with each PM2 segment. We used pandas and arcpy to select the longest intersecting feature for each PM2 segment. PM2 records that did not intersect with HPMS features were dropped from our data.

For Arizona, PM2 data received from FHWA was not linear referenced, but HPMS data were. We used the ARNOLD layer for Arizona provided by FHWA to carry out linear referencing of the data after completing data cleaning in pandas to strip the ROUTEID field in both ARNOLD and PM2 databases of excess spaces. We were then able to overlay data and identify longest intersecting features for Arizona using a process similar to the above.

Outcome Variable: Pavement Conditions

Pavement conditions were determined by FHWA and sent to GAO in the PM2 data file. Based on the pavement distress data (IRI, cracking percent, rutting, or faulting, as applicable), pavement segments were categorized as good, fair, or poor.[5]

We use the pavement condition variable SEGMENT_RATE in the PM2 data. A summary of the pavement condition data is given in table 1 based on the linked dataset. Data for 2019 were the most recent full year of available data at the time of our analysis. The number of road segments included in our in scope population of all NHS road segments is 2,601,497.

Table 1: Pavement Condition Variable for National Highway System Road Segments

	Number	Percent
Good	1,066,710	41.00
Fair	1,250,353	48.06
Poor	66,711	2.56
Missing	217,723	8.37
All	**2,601,497**	**100**

Source: GAO analysis of Federal Highway Administration data. | GAO-22-104578

Community Characteristics

To measure community characteristics, we used census tract level data from the American Community Survey five-year estimates for 2015-19. Census tracts are statistical subdivisions of counties whose boundaries follow geographic features, such as streams, highways, railroads, and legal boundaries, and that contain between 1,200 and 8,000 people. We refer to census tracts as communities for the purposes of this analysis. We produced a hierarchical dataset by overlaying each road by the census tract in which the road's midpoint was located.[6] At the lower level, these datasets contained a variable indicating the pavement condition, good, fair, or poor, of each road; at the higher level, these datasets contained the community and population characteristics for the corresponding census tract.

[5]As an alternative to the pavement condition metrics (IRI, rutting, faulting, and cracking percent), state DOTs are permitted to report present serviceability rating (PSR) for portions of mainline highways where posted speed limits are less than 40 miles per hour. See 23 C.F.R. § 490.309(b).

[6]We defined the midpoint as the x and y coordinate of the centroid of each road (i.e. each PM2 segment).

We used five-year estimates because they are the most reliable estimates at the census tract level. We focused on characteristics that captured vulnerability, such as measures included in CDC's Social Vulnerability Index.

Based on this, we selected characteristic measures to include in our analysis: the percentage of families in poverty and the percentage of population that is of an underserved racial and ethnic group, among other measures.[7] Using the definition of "equity" in Executive Order 13985 and Census categories, we define an underserved racial and ethnic group as Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino for the purposes of this report.[8]

Climate, Traffic Density, and Other Characteristics

In order to identify factors, such as climate and traffic density, that affect pavement condition and control for them in the statistical model, we conducted a literature search and interviews. The literature search was conducted by searching databases from March 2021 through May 2021. The searches were of the ProQuest and Scopus databases, included only peer-reviewed articles, and included timeframes from 2000 to 2021. Our search terms were for factors affecting pavement condition, as well as those that could identify prior studies that included a statistical model of pavement condition. The searches identified 99 articles. By reviewing the abstracts, we narrowed the list to 21 relevant articles that discussed factors that affect pavement condition or that included models analyzing pavement condition. We reviewed the full article text of the articles to create a list of variables identified as affecting pavement condition and methodological considerations for using a statistical model of pavement conditions. These variables, as well as interviews with FHWA and state DOT officials in selected states and available data, informed our selection

[7]Other measures we considered are publicly available 2018 Social Vulnerability Index (SVI) from the Centers for Disease Control and Prevention (CDC). However, we preferred to examine individual components that contribute to the SVI so that we might compare the individual contributions separately. We also considered percentage of households with children under 5 years old or over 65 years old; the percentage of population with highest education level of high school; the percentage of population without a vehicle, among others. Because these are collinear or had estimation issues, we did not include all of these factors in the model.

[8]See Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, Exec. Order No. 13985, § 2 (Jan. 20, 2021) (defining "equity").

of variables to include in the statistical model. Ultimately, we identified temperature, precipitation, vehicle weight, traffic, and being an Interstate System road segment as factors to include in the statistical model (see table 2).[9]

We created a climate variable based on the FHWA Long-Term Pavement Performance (LTPP) definition using MERRA-2 data.[10] We did not use the original LTPP climate variable because it mostly followed state boundaries. Instead, the MERRA-2 data allowed us to apply the LTPP definition to more geographically granular data. The LTPP definition classifies climate into four categories: wet-freeze, wet-non-freeze, dry-freeze, and dry-non-freeze. Because climate can vary at the sub-state level and our analysis included census tract characteristics, which are a sub-state area of geography, we preferred to capture sub-state variability in climate, which was available in the MERRA-2 data. We downloaded climate data for the United States from 1/1/2001 to 12/31/2020 to include the latest 20 years of data. According to the LTPP User Reference Guide, wet was defined as having an average precipitation of 508 mm or greater, and freeze was defined as having an average freezing index of greater than 83 degree-Celsius-days.

Population density is defined as the rural urban classification variable RUCA_CAT with values of Urban, Suburban, Large town, and Small town/isolated rural according to the Washington State Department of Health's Guidelines for Using Rural-Urban Classification Systems for Community Health Assessment Scheme 1 classification, which is based on the 2010 Rural-Urban Commuting Area (RUCA) Codes from the US Department of Agriculture's (USDA) Economic Research Services (ERS).

[9]Other variables were assessed, such as metropolitan planning area, annual average daily traffic, truck and bus traffic, percent peak single-unit traffic, and percent peak combination truck traffic, among others. Metropolitan planning organizations (MPO) are the designated policy organizations comprised of state and local officials that that are responsible for carrying out the transportation planning process in metropolitan planning areas. We obtained a shapefile of MPO areas from the Bureau of Transportation Statistics' National Transportation Atlas Database. According to the FHWA 13 Vehicle Category Classification, single-unit trucks and buses are defined as vehicle classes 4 through 7 and include pickups, vans, campers, motor homes, ambulances, and minibuses. Combination trucks are defined as vehicle classes 8 through 13 and include single trailer or multi-trailer trucks.

[10]According to FHWA, the Long-Term Pavement Performance (LTPP) program was established to collect pavement performance data.

Because pavement conditions and traffic density may differ for non-Interstate NHS and Interstate System roads, we included an indicator from the PM2 data for non-Interstate NHS roads (yes/no) in our analysis.

We used three different measures of traffic because they were individually described as important contributors to road condition and capture different aspects of traffic. We included variables for annual average daily traffic, for annual average daily traffic of single-unit trucks and buses, and annual average daily traffic for combination trucks.[11]

Table 2 contains a list of variables included in regression analyses.

Table 2: List of Variables Included in Regression Analyses

Variable (coding name)	Data source	Specification
Outcome		
Pavement condition (segment_rate)	PM2	For the statistical model: 1 Good 0 Fair/Poor For the descriptive analyses: 1 Good 2 Fair 3 Poor
Community Characteristics		
Percent underserved racial and ethnic populations (nonwhite_share)	ACS	Continuous
Percent of families in poverty (fampov_share)	ACS	Continuous
RUCA (ruca_cat)	RUCA	1 Urban (reference/excluded category) 2 Suburban 3 Large town 4 Small town, isolated rural
Traffic, Climate, Other Characteristics		
Annual Average Daily Traffic (AADT)	HPMS	Continuous, log-transformed
Single Unit, average daily traffic (aadt_sunit)	HPMS	Continuous
Combo Unit, average daily traffic (aadt_comb)	HPMS	Continuous
Interstate (nhs_int)	PM2	1 Yes 0 No (reference/excluded category)

[11]According to the FHWA 13 Vehicle Category Classification, single-unit trucks and buses are defined as vehicle classes 4 through 7, and include pickups, vans, campers, motor homes, ambulances, and minibuses. Combination trucks are defined as vehicle classes 8 through 13, and include single trailer or multi-trailer trucks.

Variable (coding name)	Data source	Specification
Climate (climate)	MERRA-2	1 Dry, no freeze (reference/excluded category) 2 Dry, freeze 3 Wet, no freeze 4 Wet, freeze
Census tract geographic identifiers (geoid)	ACS	Categorical

Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Notes: We define the percent of underserved racial and ethnic populations as the share of the population that is Non-Hispanic Black or African American, non-Hispanic American Indian and Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian and Other Pacific Islander, non-Hispanic Some Other Race, non-Hispanic population of two or more races, and Hispanic or Latino

We considered other variables that we ultimately decided not use in the analysis, such as Social Vulnerability Index (SVI), under 5, over 65, education levels, and whether the road segment is in a metropolitan planning area. We examined the correlation between SVI, under 5/over 65, under 17/over 65, highest degree earned, and percent without a vehicle, and unemployment, and found that these variables were correlated with percent of families in poverty and percent of underserved racial and ethnicity groups or had estimation issues, and therefore did not include all of them in the model. Similarly, road segments being in metropolitan planning areas was highly correlated with our rural/urban code RUCA_CAT.

Geospatial Analysis

We conducted a geospatial analysis, measuring lane miles that have pavement in good and poor condition, using counties as the geographic unit of analysis. We examined:

1. Probability maps of counties' good and poor lane miles (based on pavement condition)
2. Maps of areas with higher concentrations of poor pavement condition on the National Highway System.

To contribute to the exploration of spatial (geographic) distribution of roads with good pavement and poor pavement nationwide, we developed probability maps at the county level. We examined the rates of lane miles that have good pavement and the rates of lane miles that have poor pavement, relative to the nationwide rates of lane miles with good and poor pavement.

To produce stable estimates, we took certain steps, such as excluding counties with fewer than 30 road segments. We further excluded counties with fewer than 2 lane miles. This resulted in 2,924 counties with

2,384,278 roads and 689,187 whole lane miles, of which 325,133 whole lane miles belong to roads with good pavement.[12]

The statistical significance of rates, rather than the rates themselves, are used to classify each county as statistically higher than, statistically lower than, or statistically equal to (not different from) the nationwide rate of lane miles with good and poor pavement, for each of these measures. Differences between county and national rates are statistically significant at the 95 percent confidence level. Statistical significance is determined by one-tailed tests based on a Poisson distribution.[13] These maps allowed for the study of broad spatial distributions without considering non-significant random variations and accounted for potentially small population sizes in certain counties. These maps do not allow for a quantitative assessment of whether good or poor pavement conditions are associated with geographic areas.

Regression Analysis

We developed statistical models to estimate the likelihood of a road's pavement being in good condition based on its community characteristics, while controlling for the other characteristics in the model. For example, we assessed whether pavement in communities with high poverty rates were more or less likely to be in good condition after accounting for rates of underserved racial and ethnic populations, the climate, population density, whether the road is an Interstate, and traffic in the community. Each model included two community characteristics to capture vulnerability—percentage of underserved racial and ethnic groups and the percentage of families in poverty—along with population density, climate, traffic, and whether the NHS road is an Interstate. For computational efficiency, we selected a random sample of 50 percent of the roads, which amounted to 1,300,749 roads, to develop our regression models. Our objective was to test whether each characteristic was associated with the likelihood of pavement in good condition rather than to develop a single model that best predicted whether pavement on a

[12]We rounded the lane miles to whole lane mines.

[13]The Poisson distribution is appropriate to examine the number of occurrences—the number (or rate) of good roads or good lane lines—within a particular exposure, accounting for the number of roads or lane miles.

road would be in good condition.[14,15] Still, to assess the robustness of our model to different specifications, we examined various alternative specifications such as:

- a model that included fixed effects for each state,
- models without overall traffic or Interstate, and
- a model that included a three-way interaction among underserved racial and ethnic populations, population density, and Interstate to further assess population density and Interstate effect on the model

We used a statistical model, a hierarchical generalized linear model with a logit link function, which is suited for data with a hierarchical structure and a dichotomous outcome.[16] The data had a hierarchical structure in that each road was nested within a particular census tract. The data had a dichotomous outcome in that each road was classified as having one of two possible values of pavement, either good condition or not.[17]

Due to the logit link function, the model results express the likelihood of a road having good pavement on a log odds scale.[18] Although the coefficients estimated in our model are log-odds, they can be transformed to the odds or the probability scale.

[14]We included these characteristics in our models regardless of whether they were associated with being in good condition in bivariate tests and did not use model fit statistics, such as Akaike Information Criteria (AIC), to compare these models against each other.

[15]See for example, Raudenbush and Bryk, *Hierarchical Linear Models*, 2nd Edition (2002).

[16]Considering a continuous measure of road condition, such as the proportion of roads in a geographic area is problematic as an outcome measure for a model due to violation of assumptions of normality. For example, it is not meaningful to have negative values of good road rates, which could result from fitting a normal model to these data.

[17]Under FHWA's regulations, the possible pavement conditions are good, fair, and poor. We collapsed fair and poor in to the category of 'not good'. Because in general, most NHS roads have pavement in good or fair condition, and very few have pavement in poor condition, due to estimation issues, we were unable to model the probability of roads having pavement in poor condition.

[18]The odds = p /(1-p), where p = probability of an event. In our case, p = the probability that a road is in good condition, and the log-odds = log(p/(1-p)). Coefficients estimated in our model are on the log-odds scale and are transformed into estimated odds ratios and probabilities through appropriate transformations. Log-odds x can be transformed to the odds scale using an exponent and to the probability scale by using the transformation f(x) = 1/ (1+exp (-x)).

Because of the clustering described in the previous section, roads in the same census tract may be more similar than roads in different tracts. This similarity can persist even after accounting for community characteristics. To account for this clustering, our models included a statistical parameter, referred to as a random effect, for each census tract. All other parameters in our model representing the various community, traffic, and other characteristics in table 2 are estimated as fixed effects.

For categorical variables in our model, one category of the variable is excluded from the model.[19] The coefficient for a particular non-excluded category of that variable represents the odds ratio of a road being in good condition for that category, relative to the excluded category. For example, for population density, if the category of interest is suburban areas, then the coefficient for suburban can be examined as it is the odds ratio for suburban: the odds of a road in a suburban area having pavement in good condition relative to the odds of a road in an urban area, the excluded category, having pavement in good condition. If instead the category of interest is large towns, then the coefficient for large towns can be examined since it represents the odds of a road in a rural large town having pavement in good condition, relative to the odds of a road in an urban area having pavement in good condition. Similarly, the coefficient for small town rural for this variable represents the odds of a road in a rural small town area having pavement in good condition, relative to the odds of a road in an urban area having pavement in good condition. The excluded category is the comparison for each of the observed categories.

- An odds ratio greater than 1 means a road in the category of interest has a higher odds of having pavement in good condition, relative to a road in the excluded category.
- An odds ratio less than 1 means a road in the category of interest has a lower odds of having pavement in good condition, relative to the excluded category.

[19]In our models, the specification of a categorical variable with k distinct values is represented by k-1 binary indicators variables (1 = yes, 0 = no), referred to as dummy coding, because k-1 indicators are mathematically sufficient to represent k categories. This is because the kth category, referred to as the excluded category, is represented when all (k-1) other indicators are equal to zero. For example, for our population density variable, we have k = 4 categories (urban, suburban, large town, and small town rural), which are represented by k – 1 = 3 binary indicators as follows: suburban (1 = yes, 0 = no), large town (1 = yes, 0 = no), and small town rural (1 = yes, 0 = no). When all three of these indicators are equal to zero, that represents the excluded 4^{th} category, urban (i.e., not suburban, not large town, and not small town rural).

- An odds ratio equal to 1 means roads in the two compared categories have the same odds of having pavement in good condition.

To simplify the interpretation of the model results, we standardized each of the continuous covariates. A standardized covariate has mean of 0 and standard deviation of 1. Each such fixed effect coefficients in our model for continuous covariates can then be interpreted as providing the change in the log-odds of having pavement in good condition that is associated with a one standard-deviation increase above the average value for a particular continuous variable, for a census tract with the average random effect. Standardization changed the scale of the covariates but did not change the statistical significance of the relationships between these variables and the likelihood of having a road with good pavement.

We also transformed overall traffic into its natural logarithm to assist with model stability. See table 3 for the summary statistics for some of the characteristics within our sample. In addition to the steps described above, we took steps to help ensure the validity of our models by calculating robust standard errors, testing for model stability, and removing highly collinear variables. We present different variations in our model to show stability of results. We discussed the results of our analysis with officials from FHWA and selected states to assure we analyzed the data properly.

Table 3: Sample Summary Statistics for the American Community Survey's Estimates of Community Characteristics, 2015—2019, and Other Model Data

Community Characteristics	**Mean**	**Std. Dev.**
Percent underserved racial and ethnic populations	27.8	26.1
Percent families in poverty	10.3	8.7
Population Density[a]	**Count**	**Percent**
Urban	482,205	37.07
Suburban	237,806	18.28
Rural large town	205,109	15.77
Rural small town	374,619	28.80
Missing	1,010	0.08
Total	**1,300,749**	**100**
Other Characteristics		
Traffic[b]	**Mean**	**Std. Dev.**
Overall	23,438.5	35,224
Single Unit	1,081.1	3,022
Combination Unit	1,790.5	3,114

Climate[c]	Count	Percent
Dry, No Freeze	103,106	7.93
Dry, Freeze	56,207	4.32
Wet, No Freeze	420,681	32.34
Wet, Freeze	719,830	55.34
Missing	925	0.07
Total	**1,300,749**	**100**
Interstate Road[b]	**Count**	**Percent**
Non-Interstate	957,508	73.61
Interstate	343,235	26.39
Missing	6	0.00
Total	**1,300,749**	**100**

Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Notes: We refer to census tracts as communities for the purposes of this analysis.

In addition, 95 percent margins of errors for the ACS census tract level estimates are generally within +/-30 percentage points.

[a]USDA ERS RUCA data.

[b]FHWA HPMS data.

[c]NASA MERRA-2 data.

Data Reliability

We took several steps to assess the reliability of the data we used in our analysis. We interviewed FHWA officials and state DOT officials from select states to understand PM2, HPMS, and MERRA-2 climate data. We examined values of covariates to identify missing and invalid values. We reviewed documentation in order to assess and properly analyze these data. In order to analyze pavement conditions, we linked PM2 and HPMS from FHWA. This linkage was only successful for road segments where the two files overlapped. According to an FHWA official, because the two databases have different resolutions, some level of non-match is to be expected. In addition, an FHWA official stated that they had no reason to believe that this non-match was associated with particular locations or types of roads. FHWA also noted that some states had higher rates of missing, insufficient, or unreliable pavement condition information. However, FHWA officials noted issues, such as contract issues, rather than the condition of the pavement, caused those states to have higher rates of missing data. Since whether the pavement condition information is missing appears to be unrelated to the condition of the pavement, we have no evidence the missing data are nonignorable. Further, some states were not required to submit the full-distress data for 2019. As a sensitivity analysis, we examined our models based on data that excluded states with low linkage rates, high missing data rates, and states not required to submit full-distress data and obtained similar results to those based data that did not exclude such states. We assessed the amount of missing data in the pavement condition variable, which was less than 3 percent. We applied LTPP methodology to sub-state geographies to better capture the variation of climate.

To assess the reliability of ACS data, we took several steps. Because ACS estimates are based on a probability procedure, we chose to use 5-year data to obtain the most reliable information at the census tract level and examined and disclose the 95 percent margins of errors. We excluded from our analyses certain ACS variables that had higher rates of missing information, but that were highly correlated with other ACS variables in our analysis. For example, we excluded the measure of not having a vehicle because it had a higher missing rate, yet was correlated with other measures of financial well-being that had less missing information, such as the percentage of families in poverty. Based on the steps described above, we determined the pavement, traffic, climate, and ACS data were sufficiently reliable for assessing the relationship between community characteristics and roads with good pavement conditions.

Results

Geospatial Results

Based on our probability maps, we found that counties with significantly higher rates of lane miles with pavement in good condition, when compared to the national rate, are found throughout the nation, and there are many such counties (1154 out of 2924 counties, or 39.5%). See table 4 for the share of roads, lane miles, and counties that are higher, lower, and statistically the same when compared to nationwide rate of lane miles with pavement in good condition. Similarly, counties with significantly higher rates of lane miles with pavement in poor condition are found throughout the nation, but there are few (319 out of 2924, or 11%) such counties with higher rates of lane miles with pavement in poor condition, when compared to the nation.

Table 4: Distribution of County Rates of Lane Miles with Pavement in Good Condition, Compared to the Nationwide Rate

	County versus nationwide rate of lane miles with good pavement			
	Higher than national rate	Lower than national rate	Same as national rate	**Total**
Share of total roads	35.8%	38.9%	25.3%	**100%**
Share of total lane miles	35.9%	40.1%	24.1%	**100%**
Number (share) of counties	1154 (39.5%)	884 (30.2%)	886 (30.3%)	**2924 (100%)**

Source: GAO analysis of Federal Highway Administration and U.S. Census Bureau data. | GAO-22-104578

Note: This table represents the distribution of 2924 counties in the U.S, including Puerto Rico, that have at least 30 NHS roads and a combined total of 2 NHS lane miles. Lane miles are represented by whole lane miles through rounding. Differences between county and national rates of lane miles with pavement in good condition are statistically significant at the 95 percent confidence level. Statistical significance is determined by one-tailed tests based on a Poisson distribution.

Regression Results

The results of our models show that pavement on roads in good condition were more concentrated in communities with certain population characteristics.

Our results indicate that pavement condition is worse for communities with higher rates of underserved racial and ethnic populations, communities with higher rates of families in poverty, and urban areas. Specifically, pavement in good condition was less likely in communities with higher concentrations of underserved racial and ethnic populations, and in communities with higher concentrations of families living in poverty, even when controlling for other factors in our model, such as climate and traffic.

Table 5 shows the results of our regression model as a qualitative summary, while table 6 presents summaries based on corresponding estimated coefficients of our model. Within table 6, we present the odds ratios of a road having good pavement for our main model and sensitivity models. An odds ratio is the ratio of two odds, where, in our analysis, each odds examined the probability of a road being in good condition for a specific value of a variable within our model.[20] The direction (positive or negative) and magnitude of statistical association is determined by the coefficient estimates for the odds ratios:

- A "+" symbol in table 5 denotes an increase in the community characteristic is associated with a statistically significant increase in the likelihood of having pavement that is in good condition, and this corresponds to statistically significant odds ratio greater than one within table 6.
- A "-" symbol in table 5 denotes an increase in the community characteristic is associated with a statistically significant decrease in the likelihood of having pavement that is in good condition, and this corresponds to statistically significant odds ratio less than one in table 6.

For example, a census tract with a higher percentage of underserved racial and ethnic population has a lower likelihood of having pavement that is in good condition compared to a census tract with a lower percentage of underserved racial and ethnic population, while controlling for other community characteristics in the model, as noted by a "-" symbol in table 5 and the corresponding odds ratio that is less than one in table 6.

[20]For categorical variables, such as population density, the odds ratio is a ratio of odds for two categories of the variable: that of a non-excluded category relative to that of the excluded category. For example, the odds ratio for suburban areas is the ratio of the odds of a road having pavement in good condition in a suburban area divided by the odds of a road having pavement in good condition in an urban area, which is the excluded category. If the odds ratio is greater than one, then roads in suburban areas have a higher odds of having pavement in good condition, when compared to urban areas. Conversely, an odds ratio less than one means the roads in suburban areas have a lower odds of having pavement in good condition compared to urban areas. For continuous variables in our model, since these variables are standardized, the odds ratio represents the odds of a road having pavement in good condition that are associated with a one standard deviation increase above the mean value for that continuous variable.

Table 5: Qualitative Summary of the Relationship between Model Variables and the Likelihood of the Pavement of a Road Being in Good Condition for our Main Model

Variable	Odds-Ratio
Community Demographic	
Percent Underserved Racial and Ethnic Populations	-
Percent Families in Poverty	-
Traffic	
Log of Overall Traffic	+
Single-Unit Traffic	+
Combination Traffic	+
Population Density excluded category: Urban	
ruca_cat = 2, Suburban	+
ruca_cat = 3, Large town	+
ruca_cat = 4, Small town, isolated rural	+
Climate excluded category: Dry, No Freeze	
climate = 2, Dry, Freeze	+
climate = 3, Wet, No Freeze	+
climate = 4, Wet, Freeze	+
Interstate excluded category: non-Interstates	
nhs_int=1, Interstates	+
Observations	1,121,879
Number of groups	47,084

Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and the US Department of Agriculture's (USDA) Economic Research Services' (ERS) Rural-Urban Commuting Area (RUCA) Codes. | GAO-22-104578

Note: All coefficients are statistically significant at or above the 95 percent confidence level.

Table 6: Odds-Ratios of Pavement being in Good Condition by Underserved Ethnic and Racial Population Rate, Family Poverty Rate, Controlling for Other Variables in a model, 2019

Variable	Main Model	Include state indicators: Sensitivity 1	Exclude Interstate indicator: Sensitivity 2	Include 3-way interaction: Sensitivity 3	Exclude overall traffic: Sensitivity 4
Community Demographic					
Percent Underserved Racial and Ethnic Populations	0.705***	0.704***	0.693***	0.669***	0.729***
Percent Families in Poverty	0.926***	0.931***	0.941***	0.922***	0.903***
Traffic					
Log of Overall Traffic	1.338***	1.335***	1.569***	1.375***	Not in Model

Variable	Main Model	Include state indicators: Sensitivity 1	Exclude Interstate indicator: Sensitivity 2	Include 3-way interaction: Sensitivity 3	Exclude overall traffic: Sensitivity 4
Single-Unit Traffic	1.012***	1.010**	0.988**	0.986***	1.035***
Combination Traffic	1.183***	1.165***	1.421***	1.139***	1.191***
Population Density excluded category: Urban					
ruca_cat = 2, Suburban	3.415***	3.100***	3.891***	4.259***	2.821***
ruca_cat = 3, Large town	2.905***	2.565***	3.252***	3.412***	2.364***
ruca_cat = 4, Small town, isolated rural	4.852***	4.209***	5.888***	6.417***	3.468***
Climate excluded category: Dry, No Freeze					
climate = 2, Dry, Freeze	1.251***	1.573***	1.330***	1.238***	1.175***
climate = 3, Wet, No Freeze	1.612***	1.329***	1.636***	1.603***	1.579***
climate = 4, Wet, Freeze	1.128***	1.525***	1.204***	1.129***	1.088**
Interstate excluded category: non-Interstates					
nhs_int=1, Interstates	2.265***	2.333***	Not in Model	4.028***	3.045***
State Indicators	Not in Model	Not Displayed	Not in Model	Not in Model	Not in Model
Three-way Interaction:					
Interstate Population Density Percent Underserved Racial and Ethnic Populations	Not in Model	Not in Model	Not in Model	Not Displayed	Not in Model
Observations	1,121,879	1,121,879	1,121,879	1,121,879	1,163,900
Number of groups	47,084	47,084	47,084	47,084	47,251

Legend: *** p<0.01, ** p<0.05, * p<0.10

Source: GAO analysis of Federal Highway Administration, U.S. Census Bureau, National Aeronautics and Space Administration, and U.S. Department of Agriculture data. | GAO-22-104578

Note: For space considerations, we do not present all coefficients for certain sensitivity models. In particular, for sensitivity 1, we do not display the coefficients for state indicators, of which some were significant. For sensitivity 3, we do not present the coefficients for the two- and three-way interactions for this model, all of which were significant.

For example, based on table 6, for the underserved racial and ethnic population variable, the odds ratio is 0.70, which translates to about a 30 percent lower odds of having good pavement for a road in a community that is otherwise average, but with a 1 standard deviation increase above the average percent of “underserved racial and ethnic populations” (i.e., 53.9 percent), compared to a community with the average percent of "underserved racial and ethnic populations" (i.e., 27.8 percent).[21]

Based on table 6, for our poverty variable, the odds ratio is 0.94, which translates to about a 6 percent lower odds of having good pavement for a road in a community that is otherwise average, but with a 1 standard deviation increase above the average percent of families in poverty (i.e., 19 percent), compared to a community with the average percent of families in poverty (i.e., 10.3 percent).[22]

Below we present selected estimates from our main model to illustrate the quantitative results based on transformations of the log-odds to the predicted probability scale.

For example, for a typical census tract with the average percentage of families living in poverty, average traffic, etc., with a zero random effect, our models estimate the following for Interstate and non-Interstate roads of each population density:

- For **urban Interstate roads**, the chances of having pavement in good condition for roads in communities that are mostly (around 99 percent) white versus mostly (98 percent) underserved racial and ethnic populations: 34 versus 12 percent chance.
- For **rural Interstate roads**, the chances of having pavement in good condition for roads in communities that are mostly (around 99 percent) white versus mostly (98 percent) underserved racial and ethnic populations: 72 versus 41 percent chance.
- For **urban non-Interstate roads**, the chances of having pavement in good condition for roads in communities that are mostly (around 99 percent) white versus mostly (98 percent) underserved racial and ethnic populations: 19 percent versus 6 percent chance.
- For **rural non-interstate roads**, the chances of having pavement in good condition for roads in communities that are mostly (around 99

[21]In table 3, we see the sample mean of percent underserved racial and ethnic populations is 27.8 percent, with a standard deviation of 26.1 percent. Based on this, one standard deviation above the mean is equal to 53.9 percent = 27.8 percent + 26.1 percent.

[22]In table 3, we see the sample mean of percent of families in poverty is 10.3 percent, with a standard deviation of 8.7 percent. Based on this, one standard deviation above the mean is equal to 19 percent = 10.3 percent + 8.7 percent.

percent) white versus mostly (98 percent) underserved racial and ethnic populations: 53 percent versus 23 percent chance.

Similarly, for a typical census tract with the average percentage of underserved racial and ethnic populations, the average traffic, etc., with a zero random effect, our models estimate the following for Interstate and non-Interstate roads of each population density:

- For **urban Interstate roads**, the chances of having pavement in good condition for roads in communities with almost no (less than 1 percent) families in poverty versus those with high rates (43 percent) of families in poverty: 28 versus 22 percent chance.
- For **rural Interstate roads**, the chances of having pavement in good condition for roads in communities with almost no (less than 1 percent) families in poverty versus those with high rates (43 percent) of families in poverty: 66 versus 57 percent chance.
- For **urban non-Interstate roads**, the chances of having pavement in good condition for roads in communities with almost no (less than 1 percent) families in poverty versus those with high rates (43 percent) of families in poverty: 15 percent versus 11 percent chance.
- For **rural non-Interstate roads**, the chances of having pavement in good condition for roads in communities with almost no (less than 1 percent) families in poverty versus those with high rates (43 percent) of families in poverty: 46 percent versus 37 percent chance.

We also present the predicted probabilities for Interstate and non-Interstate roads when assessing underserved racial and ethnic populations, which show the similar pattern as when Interstate and non-Interstate roads are combined as in figures 12 and 13.

Sensitivity Analyses

In addition to our main models, we examined several variations of our models to assure the stability of our findings related to the demographic characteristics of community percent of underserved racial and ethnic populations and percent of families in poverty. These sensitivity analyses examined the following four variations of the main model:

1. include state indicators,
2. exclude Interstate System indicator,
3. include a 3-way interaction for Interstate System, percent underserved racial and ethnic populations, and population density, and
4. exclude overall traffic.

Results were consistent, regardless of our alternative specifications.[23] Specifically, the relationship between the demographic variables percentage underserved racial and ethnic populations and percentage of families in poverty, and urban areas, and the probability of a road being in good condition remain consistent: the magnitude, direction, and significance are similar to the main model. Roads in otherwise similar communities, but with higher rates of underserved racial and ethnic populations or percentage of families in poverty, had a lower likelihood of being in good condition. See table 6, where the significance, direction, and magnitude generally are similar for these different model specifications.

Discussion

Like any quantitative model, our estimates are subject to certain limitations. Our results are associational and do not imply causation. Because we analyzed population characteristics at the community level, our results cannot be used to draw inferences about the characteristics of particular individuals, families or households. For example, our results demonstrate that pavement on NHS roads within census tracts with higher rates of families in poverty has a lower likelihood of being in good condition; however, the results do not demonstrate that individuals living in poverty are more likely to live on an NHS road that has pavement in poor condition. While these two phenomena may be correlated, we did not have demographic data for individuals, families, or households on the NHS roads that would allow us to draw such inferences. Further, while we included several important factors that might be associated with poor pavement condition, like climate and traffic, there may be other factors, like funding, including pavement project funding, such as local, state, or other federal-aid highway program funds, we were unable to include in our model. As a result, pavement on roads in some communities may be less likely to be in good condition for reasons that are not accounted for by the community characteristics we examined. For example, factors related to federal highway funding may be associated with differences

[23]When our model includes interactions, the overall effect of a variable, such as the effect of the community percent of underserved racial and ethnic populations, cannot be based on the coefficient of the main effect, as it would have been a model without interactions. This is because the overall effect depends on each component within the interaction, in this case, interstate and population density. Although the interaction coefficients were significant, the resulting probabilities of a road being in good condition, for the census tract percent of underserved racial and ethnic populations or for the percent of families in poverty, holding other factors in the model constant, were similar to those for the main model.

between urban and rural pavement conditions but were not included in our model.[24]

[24]We did not control for the eligibility of pavement projects for funding provided to state DOTs through the federal-aid highway program other than National Highway Performance Program funding, any different statutory requirements for state DOTs' use of this other funding, and state DOTs' flexibilities in using it. For example, National Highway System pavement projects are also eligible for Surface Transportation Block Grant Program funding, and state DOTs must suballocate over half of this program's funding among the urban and rural areas within its state based on statutory formula. The statutory definitions of an "urban area" and a "rural area" applicable to these suballocations differ from those we used in our analysis. For the purposes of the federal-aid highway program, an "urban area" generally includes any urbanized area, which has a population of 50,000 or more, and any area having a population of 5,000 or more outside of an urbanized area, as designated by the Census Bureau. Urban area boundaries are fixed by responsible state and local officials and must be approved by FHWA. 23 U.S.C. § 101(a)(35)-(36); 49 C.F.R. § 1.85. A "rural area" is any area of the state outside of an urban area. 23 U.S.C. § 101(a)(25). However, even if a state DOT chooses to use Surface Transportation Block Grant Program funds to administer an eligible National Highway System pavement project, it may also choose not to use the suballocated funding to do so and thus the project may be located in any area in the state.

Appendix II: List of Organizations Interviewed

Table 7: List of Organizations Interviewed

Department of Transportation	Office of the Secretary of Transportation
	Federal Highway Administration
State Departments of Transportation	Alaska Department of Transportation and Public Facilities
	California Department of Transportation
	Mississippi Department of Transportation
	North Carolina Department of Transportation
	Ohio Department of Transportation
	West Virginia Department of Transportation
Metropolitan Planning Organizations	Anchorage Metropolitan Area Transportation Solutions (Alaska)
	Corvallis Area Metropolitan Planning Organization (Oregon)
	Greenville Urban Area Metropolitan Planning Organization (North Carolina)
	Gulf Regional Planning Commission (Mississippi)
	Johnson City Metropolitan Transportation Planning Organization (Tennessee)
	KYOVA Interstate Planning Commission (Kentucky, Ohio, and West Virginia)
	Laredo and Webb County Area Metropolitan Planning Organization (Texas)
	New York Metropolitan Transportation Council (New York)
	Northeast Ohio Areawide Coordinating Agency (Ohio)
	Saginaw Area Transportation Agency (Michigan)
	San Diego Association of Governments (California)
Regional Transportation Planning Organizations	Amador County Transportation Commission (California)
	Central Ohio Rural Planning Organization (Ohio)
Research and Industry Stakeholders	American Association of State Highway and Transportation Officials
	Association of Metropolitan Planning Organizations
	Center for Sustainable and Resilient Infrastructure (Virginia Tech)
	National Center for Pavement Preservation

Source: GAO. | GAO-22-104578

Appendix III: National Highway System Pavement Condition by State, as of 2019

Table 8: National Highway System Pavement Condition Classification by State and Road Type, 2019

State	Condition	Interstate Percentage of Lane Miles	Non-Interstate Percentage of Lane Miles[a]	Total Percentage of Lane Miles
Alabama	Good	72.2	41.5	50.3
	Poor	0.8	2.6	2.1
Alaska	Good	32.4	23.0	28.2
	Poor	0.7	7.0	3.6
Arizona	Good	47.9	27.4	37.1
	Poor	1.0	3.0	2.1
Arkansas	Good	67.2	32.2	42.3
	Poor	0.3	2.1	1.6
California	Good	47.9	34.1	38.7
	Poor	1.9	5.8	4.5
Colorado	Good	46.6	41.5	42.8
	Poor	2.7	3.1	3.0
Connecticut	Good	74.2	37.2	50.3
	Poor	0.1	3.6	2.4
Delaware	Good	55.8	55.0	55.1
	Poor	0.3	1.6	1.4
District of Columbia	Good	8.2	0.4	1.3
	Poor	7.7	6.8	0.4
Florida	Good	68.0	41.0	47.1
	Poor	0.5	0.3	0.4
Georgia	Good	57.0	46.5	49.2
	Poor	0.3	0.8	0.7
Hawaii	Good	19.2	20.4	20.2
	Poor	4.8	4.4	4.5
Idaho	Good	61.1	48.7	53.2
	Poor	0.5	0.5	0.5
Illinois	Good	61.1	24.3	37.8
	Poor	0.7	8.6	5.7
Indiana	Good	56.5	44.8	49.8
	Poor	0.5	0.9	0.7
Iowa	Good	66.1	39.2	45.0
	Poor	0.4	3.6	2.9
Kansas	Good	60.7	56.3	57.6
	Poor	0.3	1.5	1.2

State	Condition	Interstate Percentage of Lane Miles	Non-Interstate Percentage of Lane Miles[a]	Total Percentage of Lane Miles
Kentucky	Good	68.2	48.9	56.0
	Poor	1.1	1.4	1.3
Louisiana	Good	22.4	16.9	18.8
	Poor	2.9	12.6	9.4
Maine	Good	26.1	38.4	32.8
	Poor	0.9	7.7	4.5
Maryland	Good	54.7	32.2	38.8
	Poor	0.7	6.8	5.0
Massachusetts	Good	75.6	28.1	42.5
	Poor	0.1	2.5	1.7
Michigan	Good	63.6	37.2	44.2
	Poor	4.7	8.6	7.6
Minnesota	Good	63.5	59.1	60.2
	Poor	1.0	1.1	1.1
Mississippi	Good	70.0	35.4	44.2
	Poor	0.7	3.7	2.9
Missouri	Good	75.0	61.6	65.7
	Poor	0.1	0.9	0.6
Montana	Good	58.2	44.7	50.3
	Poor	0.3	1.3	0.9
Nebraska	Good	80.3	58.1	62.8
	Poor	0.1	2.1	1.7
Nevada	Good	81.8	67.5	72.3
	Poor	0.3	0.2	0.2
New Hampshire	Good	64.7	42.5	50.6
	Poor	0.3	2.3	1.5
New Jersey	Good	62.1	33.0	39.8
	Poor	1.8	10.7	8.6
New Mexico	Good	55.0	35.8	42.8
	Poor	0.9	2.5	1.9
New York	Good	51.2	13.2	24.2
	Poor	1.2	7.6	5.8
North Carolina	Good	70.3	36.6	46.5
	Poor	0.2	1.0	0.7
North Dakota	Good	83.6	64.9	69.3
	Poor	0.1	0.2	0.2

State	Condition	Interstate Percentage of Lane Miles	Non-Interstate Percentage of Lane Miles[a]	Total Percentage of Lane Miles
Ohio	Good	73.0	46.0	56.3
	Poor	0.1	1.7	1.1
Oklahoma	Good	61.1	38.4	45.0
	Poor	1.0	3.6	2.8
Oregon	Good	64.4	37.2	44.2
	Poor	0.2	2.4	1.9
Pennsylvania	Good	71.5	37.8	49.0
	Poor	0.4	2.0	1.5
Puerto Rico	Good	15.2	2.6	7.6
	Poor	12.0	7.8	9.5
Rhode Island	Good	50.7	16.1	23.3
	Poor	0.4	19.0	15.1
South Carolina	Good	63.4	27.8	38.0
	Poor	1.3	3.8	3.1
South Dakota	Good	75.9	55.3	61.1
	Poor	0.0	0.6	0.5
Tennessee	Good	71.5	41.3	50.3
	Poor	0.3	4.0	2.9
Texas	Good	66.6	49.2	53.3
	Poor	0.1	1.4	1.1
Utah	Good	59.5	41.2	49.4
	Poor	0.4	1.0	0.7
Vermont	Good	32.9	42.4	36.8
	Poor	0.2	4.6	2.0
Virginia	Good	58.3	36.8	42.4
	Poor	0.4	0.9	0.7
Washington	Good	40.4	7.0	25.8
	Poor	1.7	10.3	5.5
West Virginia	Good	80.6	43.0	56.8
	Poor	0.0	2.0	1.3
Wisconsin	Good	67.5	36.8	43.4
	Poor	0.3	3.1	2.5
Wyoming	Good	46.5	53.9	50.6
	Poor	1.4	0.7	1.0

Source: GAO Analysis of Federal Highway Administration (FHWA) Pavement Condition Data. | GAO-22-104578

Note: While our analysis is based on FHWA Performance Measure Rule 2 (PM2) Pavement Metric Data and Highway Performance Monitoring System (HPMS) data linked to several publicly-available data sources (see app. I), FHWA's reporting is only based on PM2 data. Therefore, the results of our analyses may differ from those reported by FHWA. According to FHWA officials, because HPMS and PM2 databases have different resolutions, some level of non-match is to be expected. For example, South Carolina, New York, and California had match rates of less than 90 percent. FHWA also noted that some states, for example, Idaho and Washington, had higher rates of missing, insufficient, or unresolved road condition information for non-Interstate National Highway System roads. Data for 2019 were the most recent full year of available data at the time of our analysis.

[a]According to FHWA officials, 10 states (Arkansas, District of Columbia, Iowa, Massachusetts, Michigan, Nevada, New Hampshire, Oregon, Texas, and Washington) set their non-Interstate National Highway System targets solely based on the International Roughness Index (IRI) metric, and were therefore not required to submit full-distress data for 2019. FHWA has published 2019 condition based only on IRI for these 10 states. However, FHWA officials told us that these states still voluntarily submitted full metric data (including IRI, as well as cracking and rutting or faulting) in preparation for the requirement in 2021, which was included in the data provided to GAO. Our analysis of these states is based on full metric data, and therefore, our numbers may differ from FHWA's reported numbers for these states.

Appendix IV: State Strategies for Managing National Highway System Pavement Condition

Statewide and Local Transportation Planning Processes

State departments of transportation (state DOTs) generally select and prioritize which eligible projects on the National Highway System, including pavement projects, will receive federal funding.[1] These decisions are generally made within the context of a statewide transportation planning process in compliance with federal requirements. For example, state DOTs must develop:

- A long-range statewide transportation plan, which establishes the state DOT's strategic vision and direction for its transportation investments for at least a 20-year period.[2]
- A state transportation improvement program (STIP), which lists and prioritizes the surface transportation projects within the state for the next 4 years. For each project, the STIP must include the estimated total project cost; proposed categories of funding; both federal and non-federal; and whether the state or a local agency will administer it.[3] State DOTs are required to submit their STIP to the Federal Highway Administration (FHWA) and the Federal Transit Administration for approval, and only projects in an approved STIP may receive federal funding. State DOTs must update their STIPs at least every 4 years.
- A transportation asset management plan (TAMP), which is a risk-based plan that describes how the state DOT will systematically operate, preserve, and improve assets, such as pavements and bridges on the National Highway System, to achieve and sustain a state of good repair over the life-cycle of the assets at minimum practicable cost.[4] The TAMP is required to include strategies that will help the state DOT make progress toward achieving its targets for asset condition and performance of the National Highway System.

In addition, metropolitan planning organizations (MPO)—the designated policy organizations comprised of state and local officials that that are

[1] *See* 23 U.S.C. § 145.

[2] 23 U.S.C. § 135(f); 23 C.F.R. § 450.216.

[3] 23 U.S.C. § 135(g); 23 C.F.R. § 450.218.

[4] 23 U.S.C. § 119(e). FHWA's regulations governing state DOTs' TAMPs are located in 23 C.F.R. Part 515.

responsible for carrying out the transportation planning process in metropolitan areas—must develop:[5]

- A long-range transportation plan, referred to as a metropolitan transportation plan, which encompasses at least 20 years and includes long- and short-range strategies and actions to ensure an effective, integrated multimodal transportation system.
- A transportation improvement program (TIP) that spans at least 4 years and includes all projects in the MPO's jurisdiction proposed to receive federal surface transportation funding within that time period. States must incorporate TIPs—either directly or by reference and without change—in their STIP.

For areas not covered by an MPO, some states permit the creation of Regional Transportation Planning Organizations (RTPO) to help coordinate transportation priorities in non-metropolitan areas.[6]

Factors Selected State DOTs Consider when Prioritizing Pavement Projects

We interviewed six state DOTs and reviewed each of their TAMPs to understand their processes for selecting and prioritizing pavement projects.[7] Based on our interviews and document reviews, we found certain commonalities regarding how states identify and select pavement projects, as described below.

States prioritize roads for pavement projects by considering various factors, including:

[5]The federal requirements applicable to the metropolitan planning for federal-aid highway program projects are primarily located in 23 U.S.C. § 134 and 23 C.F.R. Part 450. An MPO must be designated for each urbanized area within a state with a population of 50,000 or more.

[6]An RTPO is an organization that identifies local transportation needs, conducts planning, assists local governments, and supports the statewide transportation planning process in non-metropolitan regions of a state. States are authorized by statute to designate RTPOs as a method for formalizing the engagement of officials from areas with a population size of less than 50,000 as they incorporate those areas' transportation needs in the statewide transportation planning process.

[7]We selected states that varied geographically and in population levels. We also selected states that for the most part included MPOs that we had interviewed earlier in our review (which themselves were selected to ensure variation in location, climate, and community characteristics, such as population density, family poverty rate, and racial and ethnic demographics).

- pavement condition;[8]
- amount of traffic;
- strategic importance of the road, such as Interstates, or those that provide access to transportation hubs (such as airports and ports);
- federal minimum pavement condition requirements and state DOTs' self-set pavement condition targets;[9] and
- the state's long-term transportation plan

Selected state DOTs were also guided by certain principles that shaped their approach to prioritizing pavement projects. For example, the state DOTs we interviewed pursue a policy of executing projects to preserve and restore roads as opposed to allowing pavement to deteriorate to the point of needing to be fully reconstructed. Officials told us that this policy allows states to maintain roads in acceptable condition at a lower cost.

Resources Selected State DOTs Use to Inform Their Pavement Management Decisions

Based on our interviews with six state DOTs and 11 MPOs, and reviews of planning documents, state DOTs use various resources to gather information and inform their pavement management decisions.

Data and Modeling

FHWA requires that state DOTs develop and operate pavement management systems to analyze the condition of National Highway System pavements.[10] Pavement management systems can include data on various factors, such as road pavement condition, recent repair history, climate, and traffic, among other information. These systems model the future pavement condition of roads and help the state DOT select the most cost-effective pavement projects.

According to all of the six state DOTs we interviewed, pavement management systems are a key strategy for managing National Highway System pavement condition. Officials from the state DOTs noted that they

[8]However, state DOT officials told us that they do not pursue a "worst first" policy, meaning that the roads in the worst condition are not automatically given first priority.

[9]FHWA generally requires that the no more than 5 percent of a state's Interstate System lane miles may be in poor condition. State DOTs are required to establish 2-year and 4-year performance targets for pavement conditions on both the Interstate System and non-Interstate National Highway System.

[10]The purpose of these systems is to assist state DOTs in developing and implementing their TAMPs, which are required to be integrated into the statewide transportation planning process. 23 C.F.R. §§ 515.7(g), 515.9(h).

can customize their pavement management systems, allowing them to add additional variables to the model or change potential pavement interventions as necessary.

Stakeholder Input: Local DOT Offices, the Public, and Local Transportation Planning Organizations

State DOTs consult with both internal and external stakeholders to select pavement projects, including state DOTs' local division offices, the public, and local transportation planning organizations, to gain insight not captured in the pavement management system.

Officials from all of the state DOTs we interviewed noted that state DOTs' division office staff are generally aware of local considerations relevant to pavement project planning, such as the need to coordinate utility work with pavement projects. For example, Ohio's DOT has a goal that local division offices try to keep 75 percent of the pavement management system's recommended projects, but they can deviate for the remainder of the projects if appropriate. In addition to internal stakeholders, state DOTs are required to seek public comment on the proposed STIP.[11] State DOT officials from three of the selected states also consult with MPOs and, as applicable, RTPOs, when identifying pavement projects. We spoke with five MPOs that included localities that own and are responsible for maintaining portions of the National Highway System. These localities work as part of the MPO to identify and prioritize National Highway System pavement projects. Two of the five MPOs have their own pavement management system, allowing them to model pavement condition and consider different interventions.

We also found that different states give their RTPOs differing responsibilities. RTPOs may collect public input on proposed National Highway System pavement projects from localities and the public in non-metropolitan areas, as they do in Ohio. In other states, RTPOs may fulfill a role similar to MPOs, in which the state distributes funds to the RTPO among transportation projects, including National Highway System pavement projects, which the RTPOs identify and prioritize in their discretion, as is done in California.

Consideration of Program Flexibilities

State DOTs also consider the flexibility of federal-aid highway program requirements when determining how to prioritize projects and whether to use federal funding for them. Specifically, state DOT officials from all of the selected states said that they choose to use National Highway

[11] 23 U.S.C. § 135(g)(3); 23 U.S.C. § 450.210

Performance Program (NHPP) funds for highway or bridge projects as necessary given those assets' conditions.[12] In addition, officials at all of the selected state DOTs said they may use the broader flexibility of the Surface Transportation Block Grant Program to fund highway projects, including National Highway System pavement projects, instead of other transportation projects, as necessary.[13]

According to state DOT officials, five of the selected states have processes to fund minor pavement projects, such as resurfacing, solely using state funds. As a result, states can implement these projects more quickly because they do not need to adhere to all federal requirements. States have also established additional funding streams for highway projects, including pavement projects. Specifically, all of the selected states have established state gas taxes to provide further state funding for their roadway efforts. Five of the selected states have also used bonds to finance their pavement projects.

[12]Other projects eligible for NHPP funds include constructing and preserving NHS bridges and tunnels and may be used for other activities such as bridge inspections. 23 U.S.C. § 119(d). NHPP is the most well-funded federal-aid highway program, authorized at about $28.5 billion for fiscal year 2022.

[13]Surface Transportation Block Grant Program funds may be used on a much wider variety of surface transportation assets or modes, including transit, ports, and border infrastructure. In addition, projects eligible for Surface Transportation Block Grant Program funds do not need to be on the National Highway System. 23 U.S.C. § 133.

Appendix V: Comments from the Department of Transportation

U.S. Department of Transportation

Office of the Secretary of Transportation

Assistant Secretary for Administration

1200 New Jersey Ave., SE
Washington, DC 20590

July 11th, 2022

Elizabeth Repko
Director, Physical Infrastructure
U.S. Government Accountability Office (GAO)
441 G Street NW
Washington, DC 20548

Dear Ms. Repko:

The Federal Highway Administration (FHWA) is committed to supporting equity for investment in and access to the National Highway System (NHS). Using the resources and authority provided under the Bipartisan Infrastructure Law, FHWA is conducting research activities to understand inequities associated with transportation investment decisions. Through its administration of the National Highway Performance Program (NHPP) [§ 11105(1); 23 U.S.C. 119(b)], FHWA provides support for the condition and performance of the NHS, ensuring that investments of Federal-aid funds are directed to support progress toward the achievement of performance targets established in a state's asset management plan for the NHS.

The FHWA continues to improve upon its administration of the NHPP and collection and analysis of pavement condition data, including:

- Analyzing pavement Data Quality Management Programs for areas of improvement;
- Hosting stakeholders outreach activities such as webinars and peer exchanges to highlight best practices for topics such as pavement management and pavement preservation;
- Adding and maintaining data in Highway Performance Monitoring System (HPMS) in a format for use by States and FHWA and providing training and technical support to ensure HPMS data are timely and of the highest quality;
- Managing and improving the NextGen National Household Travel Survey (NHTS) to better understand traveler demographics, modes of transportation, and trip purpose; and
- Providing information on general trends and approaches related to target setting and investment tradeoff analysis.

The FHWA is also advancing its understanding of the historical ramifications of highway investments on communities, conducting research and implementing programs to rectify consequences of those investments including:

- Incorporating the White House Council on Environmental Quality's definitions of disadvantaged communities into FHWA's implementation of Justice40 covered programs; and

- Implementing the Department of Transportation's Equity Action Plan, which will reduce barriers to transportation funding for historically disadvantaged communities.

Upon review of the draft report, we partially concur with GAO's two recommendations to (1) analyze pavement condition data and examine the concentration of poor pavement in specific areas within states and differences in pavement condition by community or other characteristics, which could include race and ethnicity, poverty, or population density, and (2) identify potential strategies to help states detect and address issues that could contribute to concentrations in poor pavement and differences in pavement condition by community or other characteristics, which could include race and ethnicity, poverty, or population density. FHWA plans to broaden the study to include examining where NHPP funds are invested and examine the contributing factors driving those investment decisions. Using those results, FHWA will identify potential strategies to help states mitigate investment decision making processes that may potentially lead to inequitable outcomes. We will provide a detailed response to each recommendation within 180 days of the final report's issuance.

We appreciate the opportunity to respond to the GAO draft report. Please contact Keeva Scrivner, Deputy Director of Audit Relations and Program Improvement, at 202-366-9247 with any questions or if you would like to obtain additional details.

Sincerely,

Philip A. McNamara
Assistant Secretary for Administration

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact:

Elizabeth Repko, (202) 512-2834 or repkoe@gao.gov.

Staff Acknowledgements:

In addition to the contacts named above, the following individuals made key contributions to this report: Brandon Haller (Assistant Director); Ethan Levy (Analyst in Charge); Crystal Huggins (Analyst in Charge); Breanne Cave; Melanie Diemel; Suzanne Kaasa; Anjalique Lawrence; John Mingus; Mary-Catherine P. Overcash; Malika Rice; Pamela Snedden; Sonya Vartivarian; Michelle Weathers; Madeline Welter; and Sirin Yaemsiri.

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