Bumpy Roads Ahead:

America's Roughest Rides and Strategies to make our Roads Smoother

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Founded in 1971, TRIP ® of Washington, DC is a nonprofit organization that researches, evaluates and distributes economic and technical data on highway transportation issues. TRIP is supported by insurance companies, equipment manufacturers, distributors and suppliers; businesses involved in highway and transit engineering, construction and finance; labor unions; and organizations concerned with an efficient and safe surface transportation network.

Executive Summary

Keeping the wheel steady on America's roads and highways has become increasingly challenging as drivers encounter potholes and pavement deterioration. Nearly one-third of the nation's major urban roadways – highways and major streets that are the main routes for commuters and commerce – are in poor condition. These critical links in the nation's transportation system carry 70 percent of the approximately 3.1 trillion miles driven annually in America.

Road conditions could deteriorate even further in the future as the rate of vehicle travel continues to increase and local and state government find they are unable to adequately fund road repairs.

In this report, TRIP examines the condition of the nation's major urban roads, including pavement condition data for America's most populous urban areas, recent trends in travel, the latest developments in repairing roads and building them to last longer, and the funding levels needed to adequately address America's deteriorated roadways.

For the purposes of this report, an urban area includes the major city in a region and its neighboring or surrounding suburban areas. Pavement condition data are the latest available and are derived from the Federal Highway Administration's (FHWA) 2014 annual survey of state transportation officials on the condition of major state and locally maintained roads and highways, based on a uniform pavement rating index. The pavement rating index measures the level of smoothness of pavement surfaces, supplying information on the ride quality provided by road and highway surfaces. The major findings of the TRIP report are:

Nearly one-third of the nation's major urban roads are rated in substandard or poor condition, providing motorists and truckers with a rough ride and increasing the cost of operating a vehicle.

- The pavement data in this report, which is for all urban arterial and collector roads and highways, is provided by the Federal Highway Administration (FHWA), based on data submitted annually by state departments of transportation on the condition of major state and locally maintained roads and highways.

- Pavement data for Interstate highways and other principal arterials is collected for all system mileage, whereas pavement data for minor arterial and all collector roads and highways is based on sampling portions of roadways as prescribed by FHWA to insure that the data collected is adequate to provide an accurate assessment of pavement conditions on these roads and highways.

- Nearly one-third (32 percent) of the nation's major urban roads – Interstates, freeways and other arterial routes – have pavements that are in substandard condition and provide an unacceptably rough ride to motorists.

- An additional 39 percent of the nation's major urban roads and highways have pavements that are in mediocre or fair condition, and 28 percent are in good condition.

- Including major rural roads, 20 percent of the nation's major roads are in poor condition, 39 percent are in mediocre or fair condition, and 40 percent are in good condition.

- The following chart shows the 25 urban regions* with a population of 500,000 or greater with the highest share of major roads and highways with pavements that are in poor condition and provide a rough ride.

	500k+ URBAN AREA	STATE	PERCENT POOR
1	San Francisco--Oakland	CA	71%
2	Los Angeles--Long Beach--Santa Ana	CA	60%
3	San Jose	CA	59%
4	Detroit	MI	56%
5	Milwaukee	WI	56%
6	Bridgeport--Stamford	CT	55%
7	Omaha	NE-IA	54%
8	Oklahoma City	OK	53%
9	Grand Rapids	MI	52%
10	Tulsa	OK	49%
11	Honolulu	HI	49%
12	Cleveland	OH	49%
13	Seattle	WA	47%
14	New Haven	CT	47%
15	San Diego	CA	46%
16	Denver--Aurora	CO	45%
17	Chicago	IL-IN	44%
18	Baltimore	MD	43%
19	New York--Newark	NY-NJ	42%
20	Akron	OH	42%
21	San Antonio	TX	41%
22	Springfield	MA-CT	39%
23	Philadelphia	PA-NJ-D-M	38%
24	Boston	MA-NH	38%
25	Hartford	CT	38%

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.

- The 25 urban regions* with a population between 200,000 and 500,000 with the greatest share of major roads and highways with pavements that are in poor condition and provide a rough ride are shown in the following chart.

	2014 200-500k URBAN AREA	STATE	PERCENT POOR
1	Concord	CA	75%
2	Madison	WI	66%
3	Victorville--Hesperia--Apple Valley	CA	61%
4	Antioch	CA	60%
5	Flint	MI	56%
6	Peoria	IL	51%
7	Colorado Springs	CO	51%
8	Canton	OH	50%
9	Stockton	CA	46%
10	Jackson	MS	44%
11	Scranton	PA	42%
12	Davenport	IA-IL	40%
13	Savannah	GA	39%
14	Baton Rouge	LA	38%
15	Des Moines	IA	38%
16	Reading	PA	38%
17	Fort Wayne	IN	38%
18	Spokane	WA	37%
19	Shreveport	LA	36%
20	Santa Rosa	CA	36%
21	Thousand Oaks	CA	35%
22	Trenton	NJ	35%
23	Youngstown	OH-PA	33%
24	Modesto	CA	32%
25	South Bend	IN-MI	31%

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.

- A listing of road conditions for each urban area with a population of 500,000 or more can be found in Appendix A. Pavement condition data for urban areas with a population between 200,000 and 500,000 can be found in Appendix B.

- The average motorist in the U.S. is losing $523 annually -- $112 billion nationally -- in additional vehicle operating costs as a result of driving on roads in need of repair. Driving on roads in disrepair increases consumer costs by accelerating vehicle deterioration and depreciation, increasing the frequency of needed maintenance and requiring additional fuel consumption.

- The following chart shows the 25 urban regions* with at least 500,000 people where motorists pay the most annually in additional vehicle maintenance because of roads in poor, mediocre and fair condition.

	500K+ URBAN AREA	STATE	VOC
1	Oklahoma City	OK	$ 1,025
2	Tulsa	OK	$ 998
3	San Francisco--Oakland	CA	$ 978
4	Los Angeles--Long Beach--Santa Ana	CA	$ 892
5	Detroit	MI	$ 865
6	San Jose	CA	$ 863
7	Milwaukee	WI	$ 861
8	Omaha	NE-IA	$ 852
9	Bridgeport--Stamford	CT	$ 797
10	San Antonio	TX	$ 791
11	Denver--Aurora	CO	$ 753
12	Cleveland	OH	$ 748
13	Honolulu	HI	$ 745
14	Grand Rapids	MI	$ 742
15	New Haven	CT	$ 728
16	Chicago	IL-IN	$ 727
17	San Diego	CA	$ 722
18	Baltimore	MD	$ 708
19	Albuquerque	NM	$ 703
20	Salt Lake City	UT	$ 698
21	Seattle	WA	$ 695
22	Akron	OH	$ 690
23	Boston	MA-NH	$ 680
24	New York--Newark	NY-NJ	$ 666
25	Springfield	MA-CT	$ 665

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.

- The 25 urban regions* with a population between 200,000 and 500,000 where motorists pay the most annually in additional vehicle maintenance because of roads in poor, mediocre and fair condition are shown in the following chart.

	200-500K URBAN AREA	STATE	VOC
1	Concord	CA	$ 1,014
2	Madison	WI	$ 974
3	Antioch	CA	$ 883
4	Jackson	MS	$ 862
5	Victorville--Hesperia--Apple Valley	CA	$ 854
6	Flint	MI	$ 825
7	Colorado Springs	CO	$ 776
8	Canton	OH	$ 770
9	Peoria	IL	$ 738
10	Fort Wayne	IN	$ 734
11	Savannah	GA	$ 729
12	Stockton	CA	$ 711
13	Des Moines	IA	$ 705
14	Baton Rouge	LA	$ 698
15	Davenport	IA-IL	$ 696
16	Santa Rosa	CA	$ 663
17	Shreveport	LA	$ 661
18	Scranton	PA	$ 650
19	Provo--Orem	UT	$ 646
20	Reading	PA	$ 641
21	South Bend	IN-MI	$ 637
22	Thousand Oaks	CA	$ 629
23	Trenton	NJ	$ 629
24	Huntsville	AL	$ 619
25	Lubbock	TX	$ 613

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.

- A listing of additional vehicle operating costs due to driving on roads in substandard condition for urban areas with populations over 500,000 can be found in Appendix C. Additional vehicle operating costs for urban areas with a population between 200,000 and 500,000 can be found in Appendix D.

With vehicle travel growth returning to pre-recession rates and large truck travel anticipated to grow significantly, the result will be an increase in traffic and wear and tear on the nation's urban roads and highways. The additional travel will increase the amount of road, highway and bridge investment needed to improve conditions and to meet the nation's transportation needs.

- Vehicle travel in the U.S. increased by 15 percent from 2000 to 2015. U.S. vehicle travel during the first eight months of 2016 increased 3.1 percent from the same period in 2015.

- Travel by large commercial trucks in the U.S. increased by 26 percent from 2000 to 2014. Large trucks place significant stress on roads and highways.

- The level of heavy truck travel nationally is anticipated to increase by approximately 72 percent from 2015 to 2030, putting greater stress on the nation's roadways.

- The 2015 AASHTO Transportation Bottom Line Report found that the U.S. currently has a $740 billion backlog in improvements needed to restore the nation's roads, highways and bridges to the level of condition and performance needed to meet the nation's transportation demands.

- The 2015 AASHTO Transportation Bottom Line Report found that the nation's road, highway and bridge backlog included $392 billion in needed road and highway repairs to return them to a state of good repair; $112 billion needed in bridge rehabilitation and $237 billion in needed highway capacity expansions to relieve traffic congestion and support economic development.

The federal government is a critical source of funding for road and highway repairs. The current five-year federal surface transportation program includes modest funding increases and provides states with greater funding certainty, but falls far short of providing the level of funding needed to meet the nation's highway and transit needs. The bill does not include a long-term and sustainable revenue source.

- Signed into law in December 2015, the Fixing America's Surface Transportation Act (FAST Act), provides modest increases in federal highway and transit spending, allows states greater long-term funding certainty, and streamlines the federal project approval process. But, the FAST Act does not provide adequate funding to meet the nation's need for highway and transit improvements and does not include a long-term and sustainable funding source.

- The five-year, $305 billion FAST Act will provide approximately a 15 percent boost in national highway funding and an 18 percent boost in national transit funding over the duration of the program, which expires in 2020.

- In addition to federal motor fuel tax revenues, the FAST Act will also be funded by $70 billion in U.S. general funds, which will rely on offsets from several unrelated federal programs including the Strategic Petroleum Reserve, the Federal Reserve and U.S. Customs.

- According to the 2015 AASHTO Transportation Bottom Line Report, a significant boost in investment in the nation's roads, highways, bridges and public transit systems is needed to improve their condition and to meet the nation's transportation needs.

- AASHTO's report found that based on an annual one percent increase in VMT annual investment in the nation's roads, highways and bridges needs to increase 36 percent, from $88 billion to $120 billion, to improve conditions and meet the nation's mobility needs, based on an annual one percent rate of vehicle travel growth. Investment in the nation's public transit system needs to increase from $17 billion to $43 billion.

- The Bottom Line Report found that if the national rate of vehicle travel increased by 1.4 percent per year, the needed annual investment in the nation's roads, highways and bridges would need to increase by 64 percent to $144 billion. If vehicle travel grows by 1.6 percent annually the needed annual investment in the nation's roads, highways and bridges would need to increase by 77 percent to $156 billion.

Projects to improve the condition of the nation's roads and bridges could boost the nation's economic growth by providing significant short- and long-term economic benefits.

- Highway rehabilitation and preservation projects provide significant economic benefits by improving travel speeds, capacity and safety, and by reducing operating costs for people and businesses. Roadway repairs also extend the service life of a road, highway or bridge, which saves money by postponing the need for more expensive future repairs.

- The Federal Highway Administration estimates that each dollar spent on road, highway and bridge improvements results in an average benefit of $5.20 in the form of reduced vehicle maintenance costs, reduced delays, reduced fuel consumption, improved safety, reduced road and bridge maintenance costs, and reduced emissions as a result of improved traffic flow.

Transportation agencies can reduce pavement life cycle costs by using higher-quality paving materials that keep roads structurally sound and smooth for longer periods, and by employing a pavement preservation approach that optimizes the timing of repairs to pavement surfaces.

- There are five life cycle stages of a roadway pavement: design, construction, initial deterioration, visible deterioration and pavement disintegration and failure.

- A 2010 Federal Highway Administration report found that an over-reliance on short-term pavement repairs will fail to provide the long-term structural integrity needed in a roadway surface to guarantee the future performance of a paved road or highway.

- The 2010 Federal Highway Administration report warned that transportation agencies that focus only on current pavement surface conditions will eventually face a highway network with an overwhelming backlog of pavement rehabilitation and replacement needs.

- A properly implemented pavement preservation approach to keeping pavements in good condition has been found to reduce overall pavement life cycle costs by approximately one-third over a 25-year period.

- Initial pavement preservation can only be done on road surfaces that are structurally sound. Roads that have significant deterioration must be maintained with surface repairs until sufficient funds are available to reconstruct the road, at which time a pavement preservation strategy can be adopted.

- The use of thicker pavements and more durable designs and materials for a particular roadway are being used to increase the life span of road and highway surfaces and delay the need for significant repairs. These new pavements include high performance concrete pavements and asphalt pavements that have a perpetual pavement design.

Adequate funding allows transportation agencies to reconstruct roadways that are structurally worn out and adopt the following recommendations for ensuring a smooth ride.

- Implement and adequately fund a pavement preservation program that performs initial maintenance on road surfaces while they are still in good condition, postponing the need for significant rehabilitation.

- Use pavement materials and designs that will provide a longer-lasting surface when critical routes are constructed or reconstructed.

- Resurface roads in a timely fashion using pavement materials that are designed to be the most durable, given local climate and the level and mix of traffic on the road.

- Invest adequately to ensure that 75 percent of local road surfaces are in good condition.

All data used in the report are the latest available. Sources of information for this report include the Federal Highway Administration (FHWA), the United States Department of Transportation (USDOT), the AAA, the Texas Transportation Institute (TTI), the Transportation Research Board (TRB) and the Bureau of Labor Statistics (BLS).

Introduction

From rural to suburban to urban, America's roads give us the freedom to pursue our chosen lifestyles and provide for the tremendous movement of goods and services on which our modern lives depend.

But, the daily pounding that urban roadways endure from cars and trucks has taken a toll. From coast to coast, major streets and freeways in most U.S. communities are showing significant signs of distress. The result of this increasing stress, coupled with other factors, is that nearly one-third of urban streets and highways have rough pavements that provide a ride that many drivers find unacceptable. And one result of driving on these rough roads and highways is that the cost to own and maintain a vehicle increases because cars and trucks wear out more quickly, require more maintenance, and consume more fuel.

This report looks at the level of smoothness on the nation’s major roads and the costs to motorists of driving on roads that have pavements in poor condition. Data on pavement conditions are from the Federal Highway Administration (FHWA), which annually gathers data on the condition of the nation's major roads. These data are submitted annually to the FHWA by state departments of transportation. Although the data are gathered by the states, the roads and highways for which condition data are provided in this report are mostly maintained by state or local governments.

This report also looks at the current level of annual investment in maintaining pavements, the amount needed annually to keep roads in their current condition, and the amount needed annually to improve their condition. The report concludes with a series of recommendations for improving the condition of the nation's roads.

Vehicle Travel Trends

Increases in vehicle travel since 2000 have resulted in a significant increase in wear and tear on the nation's roads. Vehicle travel growth, which slowed significantly as a result of the nation's significant economic downturn in 2008 and subsequent slow economic recovery, have since returned to pre-recession growth rates. From 2000 to 2015, vehicle travel in the U.S. increased by 15 percent.[1] But, U.S. vehicle miles of travel increased 3.1 percent from the first eight months of 2016 compared to the first eight months of 2015.[2]

Travel by large commercial trucks, which places significant stress on paved road and highway surfaces, continues to increase at a rate approximately double the rate for all vehicles and is anticipated to continue to grow at a significant rate through 2030. Travel by large commercial trucks in the U.S. increased by 26 percent from 2000 to 2014.[3] The level of heavy truck travel nationally is anticipated to increase by approximately 72 percent from 2015 to 2030, putting greater stress on the nation's roadways.[4]

Urban Pavement Conditions

The pavement data in this report, which is for all urban arterial and collector roads and highways, is provided by the Federal Highway Administration (FHWA), based on data submitted annually by state departments of transportation on the condition of major state and locally maintained roads and highways. Pavement data for Interstate highways

and other principal arterials is collected for all system mileage, whereas pavement data for minor arterial and all collector roads and highways is based on sampling portions of roadways as prescribed by FHWA to insure the data collected is adequate to provide an accurate assessment of pavement conditions on these roads and highways.

The "ride quality" of highways and roadways is typically evaluated using the International Roughness Index (IRI), although some roads were also rated by the Present Serviceability Rating (PSR). While there may be some variance in how transportation officials apply these indices, the FHWA data are the only national source of pavement condition ratings based on a consistent criteria.

Using this information, TRIP categorizes the condition of a region's roads and highways into poor, mediocre, fair or good condition. The FHWA has found that a road surface with an IRI rating below 95 provides a good ride quality, a road with an IRI from 95 to 170 provides an acceptable ride quality, and a road with an IRI above 170 provides an unacceptable ride quality.[5] Based on the PSR scale, road surfaces rated 3.5 or higher are in good condition, a rating of 3.1 to 3.4 indicates a road is in fair condition, roads between 2.6 to 3.0 are rated in mediocre condition, and roadways that receive a PSR rating of 2.5 or less are in poor condition. The FHWA finding is based on a study that measured driver reactions to various road conditions to determine what level of road roughness was unacceptable to most drivers.[6] The scale used to rate the condition of road and highway pavements are indicated in the following chart.

Chart 1. Pavement conditions, based on IRI or PSR rating.

	IRI	PSR
Substandard (Poor)	**Above 170**	**2.5 or less**
Mediocre	**120-170**	**2.6 – 3.0**
Fair	**95-119**	**3.1 – 3.4**
Good	**0-94**	**3.5 or higher**

Source: TRIP, based on FHWA data.

An analysis of 2014 pavement data found that 32 percent of the nation's major urban roads – Interstates, freeways and other major routes – had pavements that were in substandard (poor) condition.[7] These are roads and highways that provide an unacceptable ride and are in need of resurfacing or more significant repairs. TRIP's analysis of federal highway data from 2014 also found that 39 percent of these major urban routes provided an acceptable ride quality and were in either mediocre or fair condition.[8] The remaining 28 percent of major urban highways and roads were found to provide good ride quality.[9]

The FHWA data allowed TRIP to determine how many miles of major roads in each urban area have pavements in poor, mediocre, fair or good condition. Drivers on roads rated as poor are likely to notice that they are driving on a rougher surface, which puts more stress on their vehicles. Roads rated as poor may have cracked or broken pavements. These roads often show significant signs of pavement wear and deterioration and may also have significant distress in their underlying foundation. Road or highway surfaces rated poor provide an unacceptable ride quality and are in need of resurfacing and some need to be reconstructed to correct problems in the underlying structure.

Roads rated as being in either mediocre or fair condition may also show some signs of deterioration and may be noticeably inferior to those of new pavements, but can still be improved to good condition, with cost-effective resurfacing or other preservation treatments, which will extend the service life of the road.

Although road deterioration is often accelerated by freeze-thaw cycles, found most often in the nation's northern and midwestern regions, the urban areas with the highest share of poor pavement conditions include urban areas from a variety of geographic areas. In 2014, the ten large urban areas (population of 500,000 or above) with the highest percentage of major roadways that provide poor ride quality, in order of rank, are San Francisco-Oakland, Los Angeles-Long Beach-Santa Ana, San Jose, Detroit, Milwaukee, Bridgeport-Stamford, Omaha, Oklahoma City, Grand Rapids and Tulsa.[10]

Chart 2. Urban areas* (population 500,000 or more) with highest share of major roads and highways with pavements providing an unacceptable ride quality

	500k+ URBAN AREA	STATE	PERCENT POOR
1	San Francisco--Oakland	CA	71%
2	Los Angeles--Long Beach--Santa Ana	CA	60%
3	San Jose	CA	59%
4	Detroit	MI	56%
5	Milwaukee	WI	56%
6	Bridgeport--Stamford	CT	55%
7	Omaha	NE-IA	54%
8	Oklahoma City	OK	53%
9	Grand Rapids	MI	52%
10	Tulsa	OK	49%
11	Honolulu	HI	49%
12	Cleveland	OH	49%
13	Seattle	WA	47%
14	New Haven	CT	47%
15	San Diego	CA	46%
16	Denver--Aurora	CO	45%
17	Chicago	IL-IN	44%
18	Baltimore	MD	43%
19	New York--Newark	NY-NJ	42%
20	Akron	OH	42%
21	San Antonio	TX	41%
22	Springfield	MA-CT	39%
23	Philadelphia	PA-NJ-D-M	38%
24	Boston	MA-NH	38%
25	Hartford	CT	38%

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.
Source: TRIP analysis of Federal Highway Administration data

In 2014, the mid-sized urban areas (population between 200,000 and 500,000) with the highest percentage of major roadways that provide poor ride quality, in order of rank, are Concord, Madison, Victorville-Hesperia-Apple Valley, Antioch, Flint, Peoria, Colorado Springs, Canton, Stockton and Jackson.[11]

Chart 3. Urban areas* (population between 200,000 and 500,000) with highest share of major roads and highways with pavements providing an unacceptable ride quality

	2014 200-500k URBAN AREA	STATE	PERCENT POOR
1	Concord	CA	75%
2	Madison	WI	66%
3	Victorville--Hesperia--Apple Valley	CA	61%
4	Antioch	CA	60%
5	Flint	MI	56%
6	Peoria	IL	51%
7	Colorado Springs	CO	51%
8	Canton	OH	50%
9	Stockton	CA	46%
10	Jackson	MS	44%
11	Scranton	PA	42%
12	Davenport	IA-IL	40%
13	Savannah	GA	39%
14	Baton Rouge	LA	38%
15	Des Moines	IA	38%
16	Reading	PA	38%
17	Fort Wayne	IN	38%
18	Spokane	WA	37%
19	Shreveport	LA	36%
20	Santa Rosa	CA	36%
21	Thousand Oaks	CA	35%
22	Trenton	NJ	35%
23	Youngstown	OH-PA	33%
24	Modesto	CA	32%
25	South Bend	IN-MI	31%

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas.
Source: TRIP analysis of Federal Highway Administration data

A listing of road conditions for urban areas with a population of 500,000 or more can be found in Appendix A. Pavement condition data for urban areas with a population between 200,000 and 500,000 can be found in Appendix B.

The Cost to Motorists of Deteriorated Roads

When road surfaces deteriorate, motorists are taxed in the form of additional operating costs, which are incurred by driving on roads that provide a poor ride quality. Additional vehicle operating costs have been calculated in the Highway Development and Management Model (HDM), which is recognized by the USDOT, and in more than 100 other countries, as the definitive analysis of the impact of road conditions on vehicle operating costs. The HDM report is based on numerous studies that have measured the impact of various factors, including road conditions, on vehicle operating costs.

The HDM report found that road deterioration increases ownership, repair, fuel and tire costs. The report found that deteriorated roads accelerate the depreciation of vehicles and the need for repairs because the stress on the vehicle increases in proportion to the level of roughness of the pavement surface. Similarly, tire wear and fuel consumption increase as roads deteriorate since there is less efficient transfer of power to the drive train and additional friction between the road and the tires.[12]

TRIP's additional vehicle operating cost (VOC) estimate is based on taking the average number of miles driven annually by a region's driver, calculating current vehicle operating costs based on AAA's 2015 vehicle operating costs and then using the HDM model to estimate the additional vehicle operating costs being paid by drivers as a result of substandard roads.[13] Additional research on the impact of road conditions on fuel consumption by the Texas Transportation Institute (TTI) is also factored into the TRIP methodology.[14]

TRIP estimates that driving on roads in need of repair costs the average driver $523 annually in extra vehicle operating costs - $112 billion nationwide. Individual driver operating costs may be somewhat higher or lower depending on the amount of travel by an individual driver and the type of vehicle driven, as larger vehicles tend to have greater increases in operating costs due to substandard roads.

In urban areas with a population of 500,000 or greater, Oklahoma City drivers incur the greatest annual extra vehicle operating costs due to driving on rough roads. The other nine urban regions, with at least 500,000 in population, where drivers pay the most (in order of rank) because of rough roads are: Tulsa, San Francisco-Oakland, Los Angeles-Long Beach-Santa Ana, Detroit, San Jose, Milwaukee, Omaha, Bridgeport-Stamford and San Antonio.

Chart 4. Urban areas* (population of 500,000 or more) with highest annual additional vehicle operating cost per motorists as result of driving on roads with unacceptable ride quality.

	500K+ URBAN AREA	STATE	VOC
1	Oklahoma City	OK	$ 1,025
2	Tulsa	OK	$ 998
3	San Francisco--Oakland	CA	$ 978
4	Los Angeles--Long Beach--Santa Ana	CA	$ 892
5	Detroit	MI	$ 865
6	San Jose	CA	$ 863
7	Milwaukee	WI	$ 861
8	Omaha	NE-IA	$ 852
9	Bridgeport--Stamford	CT	$ 797
10	San Antonio	TX	$ 791
11	Denver--Aurora	CO	$ 753
12	Cleveland	OH	$ 748
13	Honolulu	HI	$ 745
14	Grand Rapids	MI	$ 742
15	New Haven	CT	$ 728
16	Chicago	IL-IN	$ 727
17	San Diego	CA	$ 722
18	Baltimore	MD	$ 708
19	Albuquerque	NM	$ 703
20	Salt Lake City	UT	$ 698
21	Seattle	WA	$ 695
22	Akron	OH	$ 690
23	Boston	MA-NH	$ 680
24	New York--Newark	NY-NJ	$ 666
25	Springfield	MA-CT	$ 665

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas

Source: TRIP analysis based on Federal Highway Administration data

In urban areas with a population between 200,000 and 500,000, Concord drivers incur the greatest annual extra vehicle operating costs due to driving on rough roads. The other nine mid-sized urban regions with a population between 200,000 and 500,000, where drivers pay the most (in order of rank) because of rough roads are: Madison, Antioch, Jackson, Victorville-Hesperia-Apple Valley, Flint, Colorado Springs, Canton, Peoria and Fort Wayne.

Chart 5. Urban areas* (population between 200,000 and 500,000) with highest annual additional vehicle operating cost per motorists as result of driving on roads with unacceptable ride quality

	200-500K URBAN AREA	STATE	VOC
1	Concord	CA	$ 1,014
2	Madison	WI	$ 974
3	Antioch	CA	$ 883
4	Jackson	MS	$ 862
5	Victorville--Hesperia--Apple Valley	CA	$ 854
6	Flint	MI	$ 825
7	Colorado Springs	CO	$ 776
8	Canton	OH	$ 770
9	Peoria	IL	$ 738
10	Fort Wayne	IN	$ 734
11	Savannah	GA	$ 729
12	Stockton	CA	$ 711
13	Des Moines	IA	$ 705
14	Baton Rouge	LA	$ 698
15	Davenport	IA-IL	$ 696
16	Santa Rosa	CA	$ 663
17	Shreveport	LA	$ 661
18	Scranton	PA	$ 650
19	Provo--Orem	UT	$ 646
20	Reading	PA	$ 641
21	South Bend	IN-MI	$ 637
22	Thousand Oaks	CA	$ 629
23	Trenton	NJ	$ 629
24	Huntsville	AL	$ 619
25	Lubbock	TX	$ 613

* An urban area includes the major city in a region and its neighboring or surrounding suburban areas

Source: TRIP analysis based on Federal Highway Administration data

A listing of additional vehicle operating costs due to driving on roads in substandard condition for urban areas with populations over 500,000 can be found in Appendix C. Additional vehicle operating costs for urban areas with a population between 200,000 and 500,000

The Lifecycle of Pavement

Paved roadway surfaces are considered to have five stages in their life cycle. Each of these stages has a significant impact on the smoothness of the road surface.[15] The first stage is the initial design of the roadway, including the road's dimensions, type of materials, thickness of base and driving surfaces, and drainage system for the road, all of which have a significant impact on the quality and performance of the pavement surface.

The second stage is the actual construction or reconstruction of the road or highway surface. The quality of the construction process has a significant impact on the longevity of the pavement surface.

The third stage is the first few years in use when a roadway surface starts to experience some initial deterioration as a result of traffic volume, rain, snow, solar radiation and temperature changes. At this stage, a road surface appears to still be in good condition and generally provides a smooth ride to motorists.

The fourth stage begins when the rate of deterioration accelerates and visible signs of distress such as potholes, cracking and other distresses, which have a negative impact on driving performance, occur. If roads are not repaired at stage four, they will fall into stage five – disintegration and systematic structural failure – at which point they will need costly reconstruction to replace the affected sections of highway or roadway.

Chart 6. The five stages in the life cycle of a paved roadway surface

STAGE 1	**Design**
STAGE 2	**Construction**
STAGE 3	**Initial Deterioration**
STAGE 4	**Visible Deterioration**
STAGE 5	**Disintegration and Failure**

Source: ***At the Crossroads: Preserving our Highway Investment, 2005*****. National Center for Pavement Preservation**

Most drivers first notice that a road is deteriorating when they are jarred by driving over a surface that is rutted or uneven or when the pavement has cracked and a pothole or faulting has formed. But, these visible signs of pavement distress are usually the final stage in a process of deterioration.

Pavement failure can be caused by a combination of traffic loads and moisture. Moisture from rain or snow often works its way into road surfaces and the materials that form the road's foundation. Heavy traffic, particularly from weighty vehicles, puts stress on the road surface, increasing the likelihood that cracks or potholes may form. This process is exacerbated during periods of freezing and thawing in the late-winter and early spring, increasing the likelihood of pavement failure. Road surfaces at intersections are even more prone to deterioration because slow-moving or frequently stopping and starting traffic, particularly by heavy vehicles, subjects the pavement to higher levels of stress.

Strategies for Smooth Roads

Improving the smoothness of the nation's highways and roads is a key priority for transportation agencies. Significant progress has been made over the last decade in pavement materials, roadway surface design and pavement maintenance.

Increasingly, state and local transportation agencies are using improved pavement materials and construction practices to increase the long-term drivability of pavements. Transportation agencies also are putting more emphasis on providing earlier maintenance of pavement surfaces to extend their service life and delay the need for costly and traffic-delaying reconstruction. While these techniques may sometimes result in a higher initial cost, it is likely that this approach to pavement management will result in smoother pavements and lower long-term costs.

A solid, stable and consistent foundation below the surface of a road or highway is critical in maintaining a smooth driving surface.[16] When constructing or reconstructing a roadway, it is critical that the pavement's sub-base be adequate to support the roadway surface upon which cars and trucks will be driving. If a roadway's foundation is deficient, it will likely negatively impact pavement smoothness and increase the rate of pavement deterioration.

Once a new pavement has been built, some transportation agencies are putting greater emphasis on doing early preservation treatments on these pavements to extend the life span of roadway surfaces and to delay the need for more significant pavement rehabilitation. These initial surface treatments include sealing a road surface to prevent moisture from entering cracks in the pavement, or applying thin pavement overlays,

which improve ride quality, correct small surface irregularities and improve surface drainage and friction. For pavement preservation strategies to be most effective, they must be applied while the pavement surface is still in good condition, before any structural damage occurs.

The timing of the maintenance and rehabilitation of road surfaces is critical, impacting the cost-effectiveness of the repairs and ultimately the overall quality of a regional road network. It is estimated that a pavement preservation program can reduce the life cycle costs of a pavement surface by about one-third over a 25-year period.[17] The preventive maintenance approach may require several applications of minor sealing or resurfacing to a pavement surface over its lifetime, but reduces costs by delaying the need for more costly reconstruction.

A 2005 book from the National Center for Pavement Preservation (NCPP), ***At the Crossroads: Preserving our Highway Investment,*** recommended that transportation agencies adopt a pavement preservation strategy for the maintenance of the nation's roads and highways.[18] Instead of a reactive approach to roadway pavement maintenance that provides repairs to the road surfaces in the worst condition, the book recommends using a proactive approach that provides initial maintenance to pavements still in good condition, to significantly delay the need for costly reconstruction.

The NCPP book noted that preventive maintenance can only be performed on road surfaces that are structurally sound. All other road and highway surfaces first need to be reconstructed before a preventive maintenance approach will be effective. The book recommends that transportation agencies implement a preventive maintenance program for roads and highways that are structurally sound and in good condition. It

also suggests that transportation agencies should continue to make surface repairs to roads and highways that are not structurally sound to maintain them in reasonable condition until there is adequate funding for the reconstruction of these roads, at which point transportation agencies can then implement a preventive maintenance program for these improved roads.[19]

A report by FHWA found that an over-reliance on short-term pavement repairs will fail to provide the long-term structural integrity needed in a roadway surface to guarantee the future performance of a paved road or highway. The 2010 report, *"Beyond the Short Term: Transportation Asset Management for Long-Term Sustainability, Accountability and Performance,"* warned that transportation agencies that focus only on current pavement surface conditions will eventually face a highway network with an overwhelming backlog of pavement rehabilitation and replacement needs.[20]

Improved Pavement Materials

Since the late 1980s, there has been significant research into developing pavement materials and construction practices that will provide a road surface that is more durable and can better withstand various climates and traffic loads. The resulting pavements have been found to last longer, require less maintenance and have a lower life cycle cost.[21] A variety of pavement designs and materials have been developed since then that can be tailored to the individual requirements of various sections of roads and highways, including high performance concrete pavements and improved hot- and warm-mix asphalt pavements. Some pavement designs now call for varying material compositions

in different pavement layers and thicker bottom layers, which resist bottom-up cracking and provide a sturdier base for the top layer of pavement, which can be resurfaced periodically.[22]

Effective Pothole Patching

When a road or highway deteriorates to the point where potholes form, care should be taken to ensure that the temporary patch lasts until repairs can be made. Some temporary pothole repairs quickly show failure, creating the need for repeated patches, causing traffic delays and increasing pavement life cycle costs.

The FHWA studied a variety of pothole patching techniques to determine the best practice. The study was based on assessing 1,250 pothole patches at eight locations under varying weather conditions over a four-year period. The study found that 56 percent of the patches were still functioning by the end of the study period.[23] It also found that the most critical issue in pothole patching is the quality of the materials used to fill in the pothole. "The cost of patching the same potholes over and over because of poor-quality patching material quickly offsets any savings from the purchase of less expensive mix," the FHWA report concluded.[24] Higher grades of pothole patching material typically have aggregate mixes that are less susceptible to moisture damage and are more durable. More durable pothole patching materials are more expensive than other patching materials.

Other key variables impacting the effectiveness of pothole patches include adequate compaction of pothole fill material following the repair, the preparation of the

site for repair by removing loose material and underlying moisture, the subsequent levels of precipitation at the location, and the amount of and vehicle mix of traffic on the road.

The Cost of Needed Road, Highway and Bridge Improvements

The American Association of Transportation Officials (AASHTO) found in a recent report that the current level of investment in the nation's roads, highways and bridges is inadequate to keep them from deteriorating further and to relieve traffic congestion and improve roadway safety.

The 2015 AASHTO Transportation Bottom Line Report found that the U.S. currently has a $740 billion backlog in improvements needed to restore the nation's roads, highways and bridges to the level of condition and performance needed to meet the nation's transportation demands, including a $392 billion backlog in needed road and highway repairs to return them to a state of good repair, a $112 billion backlog in needed bridge rehabilitation and a $237 billion backlog in needed highway capacity expansions to relieve traffic congestion and support economic development.[25]

Federal Role in Funding Road Repairs

The federal government is a critical source of funding for the nation's roads, highways, bridges and transit systems and provides a significant return to states in road and bridge funding based on the revenue generated in the state by the federal motor fuel tax.

Most federal funds for highway and transit improvements are provided by federal highway user fees, largely an 18.4 cents-per-gallon tax on gasoline and a 24.4 cents-per-gallon tax on diesel fuel. Since 2008 revenue into the federal Highway Trust Fund has been inadequate to support legislatively set funding levels so Congress has transferred approximately $53 billion in general funds and an additional $2 billion from a related trust fund into the federal Highway Trust Fund.[26]

Signed into law in December 2015, the Fixing America's Surface Transportation Act (FAST Act), provides modest increases in federal highway and transit spending. The five-year bill also provides states with greater funding certainty and streamlines the federal project approval process. But, the FAST Act does not provide adequate funding to meet the nation's need for highway and transit improvements and does not include a long-term and sustainable funding source.

The five-year, $305 billion FAST Act will provide approximately a 15 percent boost in highway funding and an 18 percent boost in transit funding over the duration of the program, which expires in 2020.[27] In addition to federal motor fuel tax revenues, the FAST Act will also be funded by $70 billion in U.S. general funds, which will rely on offsets from several unrelated federal programs including the Strategic Petroleum Reserve, the Federal Reserve and U.S. Customs.

According to the 2015 AASHTO Transportation Bottom Line Report, a significant boost in investment in the nation's roads, highways, bridges and public transit systems is needed to improve their condition and to meet the nation's transportation needs. The AASHTO report found that based on an annual one percent increase in VMT that annual investment in the nation's roads, highways and bridges needs to increase by

36 percent, from $88 billion to $120 billion to improve conditions and meet the nation's mobility needs.[28] Investment in the nation's public transit system needs to increase from $17 billion to $43 billion.[29]

The 2015 AASHTO Transportation Bottom Line Report found that if the rate of vehicle travel increased by 1.4 percent per year, the needed annual investment in the nation's roads, highways and bridges would need to increase by 64 percent, to $144 billion. If vehicle travel grows by 1.6 percent annually the needed annual investment in the nation's roads, highways and bridges would need to increase by 77 percent, to $156 billion.[30]

The Impact of Transportation Projects on Economic Growth

When a roadway system is deteriorated it impedes economic performance by increasing transportation costs, slowing commerce and commuting, and burdening an economy with future transportation investment needs. Local, regional and state economic performance is improved when a region's roadway system is repaired. This economic improvement caused by investment in highway repairs is a result of the initial job creation associated with the project and the increased employment created over the long-term because of improved access, reduced transport costs and improved safety.

The level of mobility provided by a transportation system and its physical condition play a significant role in determining a region's economic effectiveness and competitiveness because it impacts the time it takes to transport people and goods, as well as the cost of travel. When a region's highway system is deteriorated, it increases costs to the public and businesses in the form of increased fuel consumption and vehicle

operating costs, increased traffic delays and additional traffic crashes. Addressing both the capacity and deteriorating condition of our highways and roadways will be increasingly important as the nation's population is projected to increase almost 30 percent by 2050.[31]

As the economy continues to recover from the economic downturn, investment in roadway repairs can help support economic growth. The preservation of roads and highways improves travel speed, capacity and safety, while reducing operating costs for people and businesses.[32] Projects that preserve existing transportation infrastructure also extend the service life of a road, highway or bridge and save money by postponing or eliminating the need for more expensive future repairs.[33]

The cost of road and bridge improvements are more than offset by the reduction of user costs associated with driving on rough roads, the improvement in business productivity, the reduction in delays and the improvement in traffic safety.

The Federal Highway Administration estimates that each dollar spent on road, highway and bridge improvements results in an average benefit of $5.20 in the form of reduced vehicle maintenance costs, reduced delays, reduced fuel consumption, improved safety, reduced road and bridge maintenance costs and reduced emissions as a result of improved traffic flow.[34]

Recommendations for Smoother Urban Roads

Increasing the smoothness of urban roads, thus reducing the additional vehicle operating costs paid by motorists for driving on deteriorated roads, requires that

transportation agencies pursue an aggressive program of constructing and reconstructing roads to high smoothness standards, conducting maintenance before roadways reach unacceptable condition and using the best practices for repairing damaged pavements.

The following practices can help to provide a smooth ride on the nation's roadways.

- ✓ Implement and adequately fund a pavement preservation program that postpones the need for significant rehabilitation by performing initial maintenance and preservation on road surfaces while they are still in good condition.
- ✓ Consider using pavement materials and designs that will provide a longer-lasting surface when critical routes are constructed or reconstructed.
- ✓ Resurface roads in a timely fashion using pavement material that is designed to be the most durable given local climate and the level and mix of traffic on the road.
- ✓ Maintain an aggressive pothole patching program that uses the best material available.
- ✓ Invest adequately to insure that 75 percent of local road surfaces are in good condition.

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