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. More than a quarter 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 53 percent of the approximately 3 trillion miles driven annually in America.

With the rate of vehicle travel returning to pre-recession levels and local and state governments unable to adequately fund road repairs while the current federal surface transportation program is set to expire on July 31, 2015, road conditions could get even worse in the future.

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) 2013 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:

More than a quarter 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.

- More than one-quarter (28 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 41 percent of the nation's major urban roads and highways have pavements that are in mediocre or fair condition, and 31 percent are in good condition.

- Including major rural roads, 18 percent of the nation's major roads are in poor condition, 40 percent are in mediocre or fair condition, and 42 percent are in good condition.

- 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 are:

Rank	Urban Area	% POOR
1	San Francisco--Oakland, CA	74%
2	Los Angeles--Long Beach--Santa Ana, CA	73%
3	Concord, CA	62%
4	Detroit, MI	56%
5	San Jose, CA	53%
6	Cleveland, OH	52%
7	New York--Newark, NY	51%
8	San Diego, CA	51%
9	Grand Rapids, MI	51%
10	Honolulu, HI	51%
11	Akron, OH	50%
12	San Antonio, TX	49%
13	Milwaukee, WI	46%
14	Riverside--San Bernardino, CA	46%
15	El Paso, TX	46%
16	Oklahoma City, OK	45%
17	Tulsa, OK	45%
18	New Haven, CT	45%
19	Bridgeport-Stamford, CT	44%
20	Birmingham, AL	43%
21	Denver--Aurora, CO	43%
22	Seattle, WA	42%
23	Omaha, NE	42%
24	Sacramento, CA	42%
25	New Orleans, LA	42%

* 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 250,000 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:

Rank	Urban Area	% POOR
1	Flint, MI	54%
2	Antioch, CA	52%
3	Santa Rosa, CA	49%
4	Trenton, NJ	48%
5	Temecula--Murrieta, CA	47%
6	Scranton, PA	46%
7	Reno, NV	46%
8	Spokane, WA	44%
9	Jackson, MS	44%
10	Lansing, MI	39%
11	Baton Rouge, LA	38%
12	Shreveport, LA	36%
13	Madison, WI	36%
14	Hemet, CA	36%
15	Stockton, CA	34%
16	McAllen, TX	33%
17	Victorville-Hesperia-Apple Valley, CA	32%
18	Davenport, IA	31%
19	Syracuse, NY	30%
20	Modesto, CA	30%
21	Oxnard, CA	30%
22	Provo--Orem, UT	30%
23	Lancaster, PA	27%
24	Fort Wayne, IN	27%
25	Ann Arbor, MI	26%

* 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 250,000 and 500,000 can be found in Appendix B.

- The average motorist in the U.S. is losing $516 annually -- $109.3 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 25 urban regions with at least 500,000 people, where motorists pay the most annually in additional vehicle maintenance because of roads in poor condition are:

Rank	Urban Area	VOC
1	San Francisco-Oakland, CA	$ 1,044
2	Los Angeles--Long Beach--Santa Ana, CA	$ 1,031
3	Concord, CA	$ 954
4	Tulsa, OK	$ 928
5	Oklahoma City, OK	$ 917
6	Detroit, MI	$ 866
7	Cleveland, OH	$ 845
8	San Jose, CA	$ 844
9	San Diego, CA	$ 843
10	San Antonio, TX	$ 838
11	El Paso, TX	$ 815
12	Riverside--San Bernardino, CA	$ 812
13	Grand Rapids, MI	$ 803
14	Akron, OH	$ 797
15	New York--Newark, NY	$ 791
16	Dallas--Fort Worth--Arlington, TX	$ 791
17	Birmingham, AL	$ 784
18	Honolulu, HI	$ 777
19	Houston, TX	$ 772
20	Sacramento, CA	$ 767
21	Milwaukee, WI	$ 753
22	Denver--Aurora, CO	$ 737
23	Omaha, NE	$ 729
24	Colorado Springs, CO	$ 723
25	New Orleans, LA	$ 713

* 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 250,000 and 500,000 where motorists pay the most annually in additional vehicle maintenance because of roads in poor condition are:

Rank	Urban Area	VOC
1	Temecula--Murrieta, CA	$ 857
2	Flint, MI	$ 839
3	Antioch, CA	$ 831
4	Jackson, MS	$ 818
5	Santa Rosa, CA	$ 811
6	Trenton, NJ	$ 764
7	Hemet, CA	$ 758
8	Reno, NV	$ 748
9	Lansing, MI	$ 733
10	Scranton, PA	$ 717
11	McAllen, TX	$ 716
12	Baton Rouge, LA	$ 705
13	Spokane, WA	$ 685
14	Madison, WI	$ 685
15	Oxnard, CA	$ 669
16	Victorville--Hesperia--Apple Valley, CA	$ 664
17	Shreveport, LA	$ 663
18	Stockton, CA	$ 657
19	Modesto, CA	$ 636
20	Davenport, IA	$ 591
21	Wichita, KS	$ 591
22	Provo--Orem, UT	$ 583
23	Ann Arbor, MI	$ 571
24	Reading, PA	$ 555
25	Corpus Christi, TX	$ 549

* 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 250,000 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, resulting in increased 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 which will be needed to improve conditions and to meet the nation's transportation needs.

- Vehicle travel increased by 39 percent from 1990 to 2008. From 2008 to 2013, the amount of vehicle travel on the nation's roadways remained largely unchanged, increasing by one half percent during the five year period.

- Vehicle travel in the U.S. increased by 1.7 percent from 2013 to 2014. U.S. vehicle travel during the first four months of 2015 increased 3.9 percent from the same period in 2014.

- Travel by large commercial trucks in the U.S. increased by 79 percent from 1990 to 2013. 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 2015 AASHTO Transportation Bottom Line Report also found that the annual needed investment in the nation's roads, highways and bridges to improve their condition and to meet the nation's transportation needs is $120 billion, assuming that vehicle travel increases at a rate of one percent per year. This level of investment is 36 percent higher than the current annual spending of $88 billion.

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

The federal government is a critical source of funding for road and highway repairs. But the lack of adequate funding beyond the expiration of the current federal surface transportation program, MAP-21 (Moving Ahead for Progress in the 21st Century Act), which expires on July 31, 2015, threatens the future condition of the nation's roads and highways.

- Signed into law in July 2012, MAP-21 (Moving Ahead for Progress in the 21st Century Act), has improved several procedures that in the past had delayed projects, MAP-21 does not address long-term funding challenges facing the federal surface transportation program.

- States are heavily reliant on the federal government to provide transportation funding. The current federal transportation legislation is set to expire on July 31, 2015.

- If Congress decides to provide additional revenues into the federal Highway Trust Fund in tandem with authorizing a new federal surface transportation program, a number of technically feasible revenue options have been identified by the American Association of State Highway and Transportation Officials.

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 which have a perpetual pavement design.

Adequate funding allows transportation agencies to reconstruct roadways that are structurally worn out and adopt the following recommendations for insuring 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, the Transportation Research Board and the Bureau of Labor Statistics.

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 tremendous 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 more than one-quarter 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 being made 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 1990 have resulted in a significant increase in wear and tear on the nation's roads. Vehicle travel growth slowed significantly as a result of the nation's significant economic downturn in 2008 and subsequent slow economic recovery, but started to return to pre-recession growth rates in 2014. From 1990 to 2008, vehicle travel in the U.S. increased by 39 percent.[1] But from 2008 to 2013, the amount of vehicle travel on the nation's roadways remained largely unchanged, increasing by one-half percent during the five-year period.[2]

Vehicle travel growth rates began to return to pre-recession levels in 2014 and increased further in early 2015. Vehicle travel in the U.S. increased by 1.7 percent from 2013 to 2014 and during the first four months of 2015 increased 3.9 percent from the same period in 2014.[3]

Travel by large commercial trucks, which places significant stress on paved road and highway surfaces, continue to increase at a rate approximately double the rate for all vehicles and are anticipated to continue to grow at a significant rate through 2030. Travel by large commercial trucks in the U.S. increased by 79 percent from 1990 to 2013.[4] 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.[5]

Urban Pavement Conditions

Every year the FHWA gathers data on the condition of the nation's major roads. These include condition data for roads that are maintained by federal, state or local governments. For this report, TRIP included condition data for all arterial routes, which includes a wide range of highways and roadways, including Interstates, limited-access freeways, city streets and routes that may be two or more lanes. 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 breaks down 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.[6] 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.[7] The scale used to rate the condition of the road and highway pavements are indicated in the following chart.

Chart 3. 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 2013 pavement data found that 28 percent of the nation's major urban roads – Interstates, freeways and other major routes – had pavements that were in substandard (poor) condition.[8] 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 2013 also found that 41 percent of these major urban routes provided an acceptable ride quality and were in either mediocre or fair condition.[9] The remaining 31 percent of major urban highways and roads were found to provide good ride quality.[10]

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 roads' service life.

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 actually include urban areas from a variety of geographic areas. In 2013, the ten large urban areas (with a 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, Concord, Detroit, San Jose, Cleveland, New York-Newark, San Diego, Grand Rapids and Honolulu.[11]

Chart 4. Urban areas (population 500,000 or more) with highest share of major roads and highways with pavements providing an unacceptable ride quality

Rank	Urban Area	% POOR
1	San Francisco--Oakland, CA	74%
2	Los Angeles--Long Beach--Santa Ana, CA	73%
3	Concord, CA	62%
4	Detroit, MI	56%
5	San Jose, CA	53%
6	Cleveland, OH	52%
7	New York--Newark, NY	51%
8	San Diego, CA	51%
9	Grand Rapids, MI	51%
10	Honolulu, HI	51%
11	Akron, OH	50%
12	San Antonio, TX	49%
13	Milwaukee, WI	46%
14	Riverside--San Bernardino, CA	46%
15	El Paso, TX	46%
16	Oklahoma City, OK	45%
17	Tulsa, OK	45%
18	New Haven, CT	45%
19	Bridgeport-Stamford, CT	44%
20	Birmingham, AL	43%
21	Denver--Aurora, CO	43%
22	Seattle, WA	42%
23	Omaha, NE	42%
24	Sacramento, CA	42%
25	New Orleans, LA	42%

* 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 2013, the mid-sized urban areas (with a population between 250,000 and 500,000) with the highest percentage of major roadways that provide poor ride quality, in order of rank, are Flint, Antioch, Santa Rosa, Trenton, Temecula-Murrieta, Scranton, Reno, Spokane, Jackson and Lansing.[12]

Chart 5. Urban areas (population between 250,000 and 500,000) with highest share of major roads and highways with pavements providing an unacceptable ride quality

Rank	Urban Area	% POOR
1	Flint, MI	54%
2	Antioch, CA	52%
3	Santa Rosa, CA	49%
4	Trenton, NJ	48%
5	Temecula--Murrieta, CA	47%
6	Scranton, PA	46%
7	Reno, NV	46%
8	Spokane, WA	44%
9	Jackson, MS	44%
10	Lansing, MI	39%
11	Baton Rouge, LA	38%
12	Shreveport, LA	36%
13	Madison, WI	36%
14	Hemet, CA	36%
15	Stockton, CA	34%
16	McAllen, TX	33%
17	Victorville-Hesperia-Apple Valley, CA	32%
18	Davenport, IA	31%
19	Syracuse, NY	30%
20	Modesto, CA	30%
21	Oxnard, CA	30%
22	Provo--Orem, UT	30%
23	Lancaster, PA	27%
24	Fort Wayne, IN	27%
25	Ann Arbor, MI	26%

* 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 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 250,000 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.[13]

TRIP's additional vehicle operating cost 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 2014 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.[14] Additional research on the impact of road conditions on fuel consumption by the Texas Transportation Institute (TTI) is also factored into the TRIP methodology.[15]

TRIP estimates that driving on roads in need of repair costs the average driver $516 annually in extra vehicle operating costs. 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, San Francisco-Oakland 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: Los Angeles-Long Beach-Santa Ana, Concord, Tulsa, Oklahoma City, Detroit, Cleveland, San Jose, San Diego and San Antonio.

Chart 6. 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.

Rank	Urban Area	VOC
1	San Francisco-Oakland, CA	$ 1,044
2	Los Angeles--Long Beach--Santa Ana, CA	$ 1,031
3	Concord, CA	$ 954
4	Tulsa, OK	$ 928
5	Oklahoma City, OK	$ 917
6	Detroit, MI	$ 866
7	Cleveland, OH	$ 845
8	San Jose, CA	$ 844
9	San Diego, CA	$ 843
10	San Antonio, TX	$ 838
11	El Paso, TX	$ 815
12	Riverside--San Bernardino, CA	$ 812
13	Grand Rapids, MI	$ 803
14	Akron, OH	$ 797
15	New York--Newark, NY	$ 791
16	Dallas--Fort Worth--Arlington, TX	$ 791
17	Birmingham, AL	$ 784
18	Honolulu, HI	$ 777
19	Houston, TX	$ 772
20	Sacramento, CA	$ 767
21	Milwaukee, WI	$ 753
22	Denver--Aurora, CO	$ 737
23	Omaha, NE	$ 729
24	Colorado Springs, CO	$ 723
25	New Orleans, LA	$ 713

* 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 250,000 and 500,000, Temecula-Murrieta 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 250,000 and 500,000, where drivers pay the most (in order of rank) because of rough roads are: Flint, Antioch, Jackson, Santa Rosa, Trenton, Hemet, Reno, Lansing and Scranton.

Chart 7. Urban areas (population between 250,000 and 500,000) with highest annual additional vehicle operating cost per motorists as result of driving on roads with unacceptable ride quality

Rank	Urban Area	VOC
1	Temecula--Murrieta, CA	$ 857
2	Flint, MI	$ 839
3	Antioch, CA	$ 831
4	Jackson, MS	$ 818
5	Santa Rosa, CA	$ 811
6	Trenton, NJ	$ 764
7	Hemet, CA	$ 758
8	Reno, NV	$ 748
9	Lansing, MI	$ 733
10	Scranton, PA	$ 717
11	McAllen, TX	$ 716
12	Baton Rouge, LA	$ 705
13	Spokane, WA	$ 685
14	Madison, WI	$ 685
15	Oxnard, CA	$ 669
16	Victorville--Hesperia--Apple Valley, CA	$ 664
17	Shreveport, LA	$ 663
18	Stockton, CA	$ 657
19	Modesto, CA	$ 636
20	Davenport, IA	$ 591
21	Wichita, KS	$ 591
22	Provo--Orem, UT	$ 583
23	Ann Arbor, MI	$ 571
24	Reading, PA	$ 555
25	Corpus Christi, TX	$ 549

* 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 250,000 and 500,000 can be found in Appendix D.

The Life Cycle of Pavements

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.[16] 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 occur, which have a negative impact on driving performance. If roads are not repaired at stage four, they will then 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 8. 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.[17] 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.[18] 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) recommended that transportation agencies adopt a pavement preservation strategy for the maintenance of the nation's roads and highways.[19] Instead of a reactive approach to roadway pavement maintenance that provides repairs to the road surfaces in the worst condition, the report 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 report 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 report recommends that transportation agencies implement a preventive maintenance program for roads and highways that are structurally sound and in good condition. The

report 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.[20]

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.[21]

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.[22] A variety of pavement designs and materials since then have been developed 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.[23]

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 fail, creating the need for repeated patches, causing traffic delays and increasing pavement lifecycle 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.[24] 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.[25] 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 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.[26]

The 2015 AASHTO Transportation Bottom Line Report found that the annual needed investment in the nation's roads, highways and bridges to improve their condition and to meet the nation's transportation needs is $120 billion, assuming that vehicle travel increases at a rate of one percent per year.[27] This level of investment is 36 percent higher than the current annual spending of $88 billion.[28]

The 2015 AASHTO Transportation Bottom Line Report found that if the rate of vehicle travel increased by 1.4 percent per year that the needed annual investment in the

nation's roads, highways and bridges would increase to $144 billion and if vehicle travel grows by 1.6 percent annually the needed annual investment in the nation's roads, highways and bridges would be $156 billion.[29]

Federal Role in Funding Road Repairs

The federal government is a critical source of funding for the nation's roads, highways and bridges, providing funds largely as part MAP-21 (Moving Ahead for Progress in the 21st Century Act), the current federal surface transportation program, which expires on July 31, 2015 after a series of short term extensions.

Federal funds for highway and transit improvements are provided through the federal Highway Trust Fund, which raises revenue through federal 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.[30]

Signed into law in July 2012, MAP-21 has improved several procedures that in the past had delayed projects. However, MAP-21 does not address long-term funding challenges facing the federal surface transportation program. The current federal transportation legislation was initially set to expire on September 30, 2014 but congress passed an eight- month extension through May 31, 2015. Prior to the expiration of the eight month extension, Congress passed another two-month extension that is set to expire

on July 31, 2015. If Congress decides to provide additional revenues into the federal Highway Trust Fund in tandem with authorizing a new federal surface transportation program, a number of technically feasible revenue options have been identified by the American Association of State Highway and Transportation Officials.

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 increases almost 30 percent by 2050.[31]

As the nation's 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 because of 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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