

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

These days, potholes and pavement deterioration make it a challenge to keep the wheel steady on America's roads and highways. 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 78 percent of the approximately 2 trillion miles driven annually in urban America.

With state and local governments unable to adequately fund road repairs and with the current federal surface transportation program set to expire on September 30, 2014, 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) 2011 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 with a rough ride and increasing the cost of operating a vehicle.

- More than one-quarter (27 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 27 percent of the nation's major urban roads and highways have pavements that are in mediocre condition, 15 percent are in fair condition and 31 percent are in good condition.
- Including major rural roads, 14 percent of the nation's major roads are in poor condition, 19 percent are in mediocre condition, 17 percent are in fair condition and 50 percent are in good condition.

- The twenty urban regions with a population of 500,000 or greater 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*	Pct. Poor
1	Los Angeles--Long Beach--Santa Ana	64%
2	San Francisco—Oakland	60%
3	San Jose	56%
4	San Diego	55%
5	Tucson	53%
6	New York City—Newark	51%
7	Bridgeport—Stamford	51%
8	Milwaukee	48%
9	New Orleans	47%
10	Oklahoma City	47%
11	Tulsa	46%
12	Seattle	45%
13	Honolulu	43%
14	Sacramento	43%
15	Concord, CA	42%
16	New Haven	42%
17	Riverside--San Bernardino	39%
18	Springfield, MA	39%
19	Boston	39%
20	Hartford	38%

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

- The twenty 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*	Pct. Poor
1	Antioch, CA	64%
2	Reno, NV	55%
3	Santa Rosa, CA	51%
4	Trenton, NJ	48%
5	Hemet, CA	48%
6	Spokane, WA	45%
7	Jackson, MS	45%
8	Temecula-Murrieta, CA	43%
9	Worcester, MA	41%
10	Stockton, CA	40%
11	Corpus Christi, TX	40%
12	Des Moines, IA	38%
13	Madison, WI	37%
14	South Bend, IN	34%
15	Davenport, IA	34%
16	Baton Rouge, LA	32%
17	Scranton, PA	32%
18	Fort Wayne, IN	32%
19	Modesto, CA	31%
20	Anchorage, AK	29%

* 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 \$377 annually -- \$80 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 twenty 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*	Annual VOC
1	Los Angeles--Long Beach--Santa Ana	\$832
2	Tulsa	\$784
3	San Francisco—Oakland	\$782
4	Oklahoma City	\$782
5	San Diego	\$758
6	San Jose	\$737
7	Tucson	\$723
8	Milwaukee	\$700
9	New Orleans	\$687
10	New York City--Newark	\$673
11	Bridgeport--Stamford	\$669
12	Sacramento	\$658
13	Riverside--San Bernardino	\$638
14	Seattle	\$625
15	Concord, CA	\$623
16	Denver--Aurora	\$615
17	Dallas--Fort Worth--Arlington	\$615
18	Birmingham	\$601
19	Honolulu	\$598
20	Colorado Springs	\$589

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

- The twenty 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*	Annual VOC
1	Antioch, CA	\$793
2	Reno, NV	\$771
3	Jackson, MS	\$741
4	Hemet, CA	\$738
5	Santa Rosa, CA	\$709
6	Temecula-Murrieta, CA	\$664
7	Trenton, NJ	\$636
8	Spokane, WA	\$619
9	Madison, WI	\$615
10	Corpus Christi, TX	\$614
11	Worcester, MA	\$600
12	Des Moines, IA	\$591
13	Stockton, CA	\$584
14	Baton Rouge, LA	\$581
15	Modesto, CA	\$560
16	Shreveport, LA	\$549
17	Davenport, IA	\$548
18	Scranton, PA	\$539
19	Oxnard, CA	\$534
20	Fort Wayne, IN	\$530

* 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](#).

Significant increases in travel in the years ahead will put additional stress on roads and make it even more costly to improve and maintain them.

- Overall vehicle travel increased by 37 percent from 1990 to 2011. Travel by large commercial trucks grew at an even faster rate, increasing by 49 percent from 1990 to 2011. Large trucks place significant stress on road surfaces.
- Vehicle travel is expected to increase approximately 25 percent by 2030, and the level of heavy truck travel nationally is anticipated to increase by approximately 64 percent by 2030, putting greater stress on our nation's roadways.

Pavement conditions are likely to worsen under current funding by all levels of government. Through 2032, the U.S. faces a \$156 billion shortfall in the cost to maintain roadways in their current condition, a \$374 billion shortfall to make modest improvements in pavement conditions and a \$670 billion shortfall in the cost to make significant improvements to roadway conditions.

- A [2010 U.S. Department of Transportation \(USDOT\) study](#) prepared for Congress found that road and highway pavement conditions are likely to worsen at current funding levels, largely because numerous roadways currently or soon will require significant rehabilitation or reconstruction to extend their service life.
- All levels of government (local, state and federal) are currently spending \$36.5 billion annually on the rehabilitation and preservation of the physical condition of roads and highways (excluding bridge repairs).
- The DOT study estimates that the annual investment needed to maintain roads and highways (excluding bridges) in their current condition is \$44.3 billion annually - a 21 percent increase from current levels of annual funding.
- The DOT study estimates that the annual investment needed to make a modest improvement in the condition of roads and highways (excluding bridges) is \$55.2 billion annually - a 51 percent increase in annual funding.
- Needed annual investment to significantly improve the condition of roads and highways (excluding bridges) is \$70 billion annually - a 91 percent increase in annual funding.

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 September 30, 2014, threatens the future condition of the nation's roads and highways.

- Signed into law in July 2012, MAP-21 will provide approximately \$38 billion annually for road, highway and bridge improvements annually in fiscal years 2013 and 2014.
- The MAP-21 program, approved by Congress in 2012, greatly increased funding flexibility for states and streamlined project approval processes to improve the efficiency of state and local transportation agencies in providing needed transportation improvements.

- MAP-21 does not provide sufficient long-term revenues to support the current level of federal surface transportation investment. Nationwide federal funding for highways is expected to be cut back by almost 100 percent from the current investment level for the fiscal year starting on October 1, 2014 (FY 2015) unless Congress provides additional transportation revenues. This is due to a cash shortfall in the Highway Trust Fund as projected by the Congressional Budget Office.

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 preservation projects provide significant economic benefits by improving travel speeds, capacity, load-carrying abilities 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 either postponing or eliminating the need for more expensive future repairs.
- A [2007 analysis by the Federal Highway Administration](#) found that every \$1 billion invested in highway construction would support approximately 27,800 jobs, including approximately 9,500 in the construction sector, approximately 4,300 jobs in industries supporting the construction sector, and approximately 14,000 other jobs induced in non-construction related sectors of the economy.
- 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 adopting a pavement preservation approach that emphasizes making early initial repairs to pavement surfaces while they are still in good condition and using higher-quality paving materials, reducing the cost of keeping roads smooth by delaying the need for costly reconstruction.

- There are five life-cycle stages of a paved surface: 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 preventive maintenance 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 perpetual hot mix asphalt pavements.

Adequate funding would allow transportation agencies to 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.
- 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 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 insure 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.

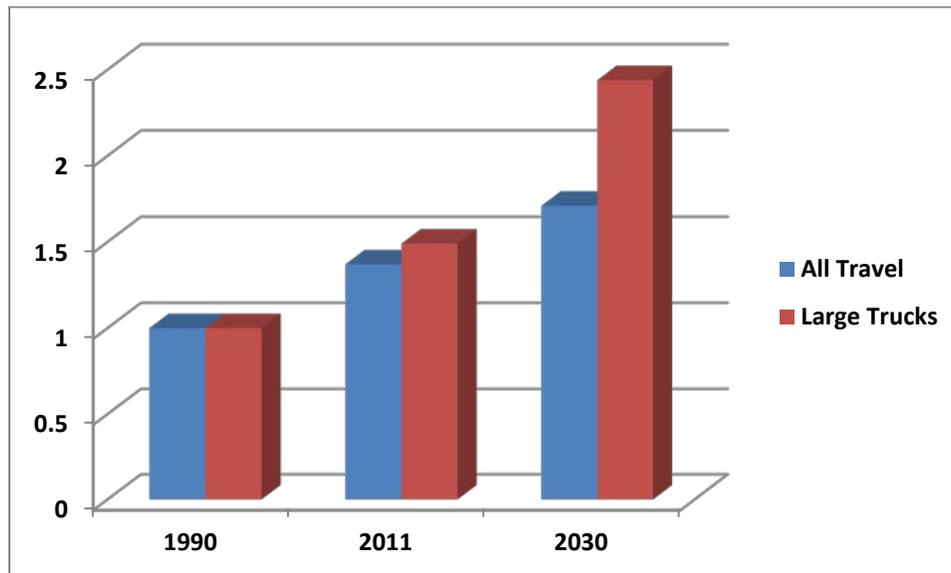
This report also looks at the current level of annual investment being made in maintaining pavements, the amount needed annually to keep roads in their current condition, and the amount needed annually to improve their condition. The report

concludes with a series of recommendations for improving the condition of the nation's roads.

Trends in Vehicle Travel

Increases in vehicle travel since 1990 have resulted in a significant increase in wear and tear on the nation's roads. Travel by large commercial trucks, which place a significant amount of stress on a roadway, increased by 49 percent from 1990 to 2011.¹ Overall vehicle travel increased by 37 percent from 1990 to 2011.²

Chart 1. Increase in travel by all vehicles and by large commercial trucks from 1990 to 2011 and 2030.
(1 = 100 percent of 1990 total)



Source: TRIP analysis of FHWA data

Vehicle travel on the nation's roads is expected to continue to increase, making it even more difficult to keep urban roads in good condition in the future. Overall vehicle

travel is expected to increase by approximately 25 percent by the year 2030 and the level of heavy truck travel nationally is anticipated to increase by approximately 64 percent by the year 2030, according to FHWA projections.³

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.⁴ 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.⁵ 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 2011 pavement data found that 27 percent of the nation’s major urban roads – Interstates, freeways and other major routes – had pavements that were in substandard (poor) condition.⁶ 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 2011 also found that 42 percent of these major urban routes provided an acceptable ride quality and were in either mediocre or fair condition.⁷ The remaining 31 percent of major urban highways and roads were found to provide good ride quality.⁸

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 surface.

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 surface 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 2011, 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 Los Angeles—Long Beach—Santa Ana, San Francisco – Oakland, San Jose, San Diego, Tucson, New York City—Newark, Bridgeport-Stamford (CT), Milwaukee, New Orleans and Oklahoma City.⁹

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*	Pct. Poor
1	Los Angeles--Long Beach--Santa Ana	64%
2	San Francisco--Oakland	60%
3	San Jose	56%
4	San Diego	55%
5	Tucson	53%
6	New York City--Newark	51%
7	Bridgeport--Stamford	51%
8	Milwaukee	48%
9	New Orleans	47%
10	Oklahoma City	47%
11	Tulsa	46%
12	Seattle	45%
13	Honolulu	43%
14	Sacramento	43%
15	Concord, CA	42%
16	New Haven	42%
17	Riverside--San Bernardino	39%
18	Springfield, MA	39%
19	Boston	39%
20	Hartford	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 2011, 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 Antioch, CA, Reno, NV, Santa Rosa, CA, Trenton, NJ, Hemet, CA, Spokane, WA, Jackson, MS, Temecula-Murrieta, CA, Worcester, MA and Stockton, CA.¹⁰

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*	Pct. Poor
1	Antioch, CA	64%
2	Reno, NV	55%
3	Santa Rosa, CA	51%
4	Trenton, NJ	48%
5	Hemet, CA	48%
6	Spokane, WA	45%
7	Jackson, MS	45%
8	Temecula-Murrieta, CA	43%
9	Worcester, MA	41%
10	Stockton, CA	40%
11	Corpus Christi, TX	40%
12	Des Moines, IA	38%
13	Madison, WI	37%
14	South Bend, IN	34%
15	Davenport, IA	34%
16	Baton Rouge, LA	32%
17	Scranton, PA	32%
18	Fort Wayne, IN	32%
19	Modesto, CA	31%
20	Anchorage, AK	29%

* 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.¹¹

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 2012 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.¹² Additional research on the impact of road conditions on fuel consumption by the Texas Transportation Institute (TTI) is also factored into the TRIP methodology.¹³

TRIP estimates that driving on roads in need of repair costs the average driver \$377 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, Los Angeles – Long Beach – Santa Ana 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, Oklahoma City, San Diego, San Jose, Tucson, Milwaukee, New Orleans and New York City—Newark.

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*	Annual VOC
1	Los Angeles--Long Beach--Santa Ana	\$832
2	Tulsa	\$784
3	San Francisco--Oakland	\$782
4	Oklahoma City	\$782
5	San Diego	\$758
6	San Jose	\$737
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8	Milwaukee	\$700
9	New Orleans	\$687
10	New York--Newark	\$673
11	Bridgeport--Stamford	\$669
12	Sacramento	\$658
13	Riverside--San Bernardino	\$638
14	Seattle	\$625
15	Concord, CA	\$623
16	Denver--Aurora	\$615
17	Dallas--Fort Worth--Arlington	\$615
18	Birmingham	\$601
19	Honolulu	\$598
20	Colorado Springs	\$589

* 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, Antioch, CA 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: Reno, NV, Jackson, MS, Hemet, CA, Santa Rosa, CA, Temecula-Murrieta, CA, Trenton, NJ, Spokane, WA, Madison, WI, and Corpus Christi, TX.

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*	Annual VOC
1	Antioch, CA	\$793
2	Reno, NV	\$771
3	Jackson, MS	\$741
4	Hemet, CA	\$738
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8	Spokane, WA	\$619
9	Madison, WI	\$615
10	Corpus Christi, TX	\$614
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15	Modesto, CA	\$560
16	Shreveport, LA	\$549
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19	Oxnard, CA	\$534
20	Fort Wayne, IN	\$530

* 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.¹⁴ 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 durability 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. 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. U.S. Department of Transportation/Federal Highway Administration

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 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 durability 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 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.¹⁵ 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 reduce 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, preventative maintenance 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, with no apparent deterioration.

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 preventive maintenance program can reduce the life cycle costs of a pavement surface by about one-third over a 25-year period.¹⁶ 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 (NCP) recommended that transportation agencies adopt a pavement preservation strategy for the maintenance of the nation's roads and highways.¹⁷ 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 NCP 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.¹⁸

A recent FHWA 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 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.¹⁹

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.²⁰ 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 mix asphalt

pavements. Some pavement designs now call for thicker bottom layers, which resist bottom-up cracking and provide a sturdier base for the top layer of pavement, which can be resurfaced periodically.²¹

Effective Pothole Repair

When a road or highway deteriorates to the point where potholes form, care should be taken to insure that the repair will last as long as possible, which will extend the life of the pavement and avoid premature repairs and associated traffic delays. Some pothole repairs quickly show signs of cracking or fail completely, creating the need for repeated repairs, causing traffic delays and increasing costs.

The FHWA studied a variety of pothole repair 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 repairs were still functioning by the end of the study period.²² It also found that the most critical issue in pothole repair 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.²³ 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 repair 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.

Funding Level Required to Improve Urban Road Smoothness

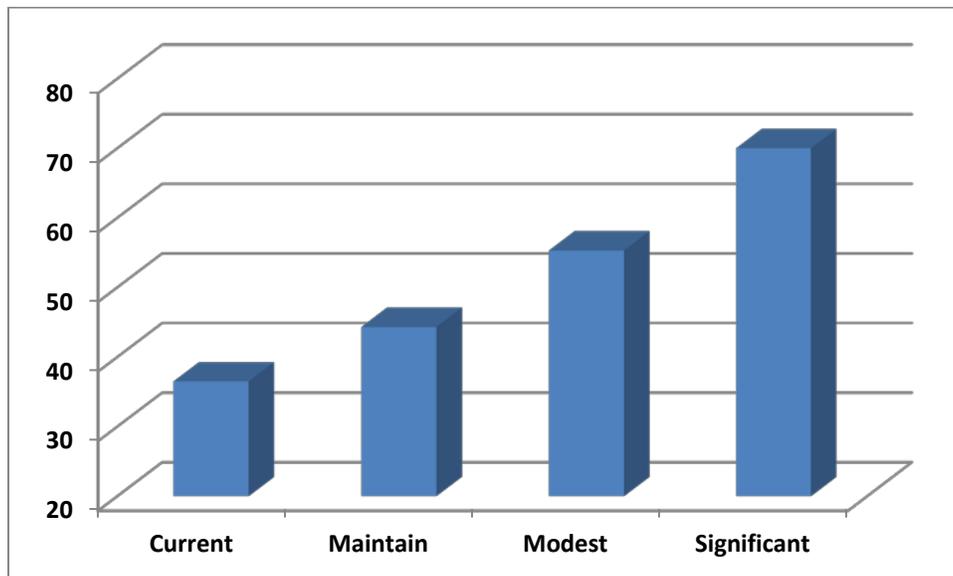
The U.S. Congress requires the U.S. Department of Transportation to provide a semi-annual comprehensive report on the condition, use and funding needs of the nation's surface transportation program. The most recent report, the [*2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*](#), found that current levels of investment by all levels of government in maintaining the physical condition of urban roads are inadequate.

The USDOT report estimated the current level of investment in preserving roads and highways and calculated what level of annual investment would be required to either maintain physical conditions at their current level or to improve physical conditions. The report estimated current and needed spending in 2010 dollars, which has been converted to 2013 dollars by TRIP.

At the current level of investment in the nation's roads and highways, overall pavement conditions can be expected to get worse, unless funding is increased, based on the findings of the 2010 USDOT report to Congress. The report found that all levels of governments are spending \$36.5 billion annually to preserve the physical condition of the nation's roads (excluding bridges).²⁴

However, the USDOT estimates that the annual investment needed to maintain the nation’s roads and highways (excluding bridge repairs) in their current condition is \$44.3 billion annually, a 21 percent increase over current levels of funding.²⁵ The U.S. DOT also estimates that the annual investment needed to make a modest improvement in the condition of the nation’s roads and highways is \$55.2 billion annually, a 51 percent increase and the current annual investment. The annual investment needed to make a significant improvement in the condition of the nation’s roads and bridges is \$70 billion annually, a 91 percent increase in annual funding.²⁶

Chart 9. Current annual funding, annual funding needed to maintain conditions and annual funding needed to achieve modest and significant improvements to pavement conditions (in billions of 2013 dollars).



Source: TRIP analysis of 2010 Status of the Nation’s Highways, Bridges, and Transit: Conditions and Performance, U.S. Department of Transportation

Through 2032, the U.S. faces a \$156 billion shortfall in the cost to maintain roadways in their current condition, a \$374 billion shortfall to make modest improvements in pavement conditions and a \$670 billion shortfall in the cost to make

significant improvements to roadway conditions, based on the findings of a USDOT study.²⁷

Federal Role in Funding Road Repairs

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 MAP-21 (Moving Ahead for Progress in the 21st Century Act) federal surface transportation legislation on September 30, 2014, threatens the future condition and performance of the nation's roads and highways.

Signed into law in July 2012, MAP-21 (Moving Ahead for Progress in the 21st Century Act), will fund surface transportation programs in the U.S. at approximately \$38 billion annually for road, highway and bridge improvements in fiscal years 2013 and 2014.²⁸

The MAP-21 program greatly increased funding flexibility for states and streamlined project approval processes to improve the efficiency of state and local transportation agencies in providing needed transportation improvements. But MAP-21 did not provide sufficient long-term revenues to support the current level of federal surface transportation investment. Nationwide federal funding for highways is expected to be cut back by almost 100 percent from the current investment level in the federal fiscal year starting October 1, 2014 (FY 2015) unless additional revenues are provided to the federal Highway Trust Fund.²⁹ This is due to a cash shortfall in the Highway Trust Fund as projected by the Congressional Budget Office.

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.

As the nation's economy continues to recover from the economic downturn, investment in roadway repairs can help support economic growth. A [2007 analysis by the Federal Highway Administration](#) found that every \$1 billion invested in highway construction would support approximately 27,800 jobs, including approximately 9,500 in the construction sector, approximately 4,300 jobs in industries supporting the construction sector, and approximately 14,000 other jobs induced in non-construction related sectors of the economy.³⁰

The preservation of roads and highways improves travel speed, capacity, load-carry abilities and safety, while reducing operating costs for people and businesses.³¹

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.³²

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.³³

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 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 repair program that uses the best patching material available.
- ✓ Invest adequately to insure that 75 percent of local road surfaces are in good condition.

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Endnotes

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- ² Ibid.
- ³ The VMT projection is based on TRIP analysis of FHWA data. The estimated increase in large commercial truck travel is based on the Freight Analysis Framework, developed by the U.S. Department of Transportation.
- ⁴ 2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, U.S. Department of Transportation. Exhibit 3-1.
- ⁵ A Statistical Analysis of Factors Associated With Perceived Road Roughness by Drivers, K. Shafizadeh, University of Washington, F. Mannering, Purdue University, (2002).
- ⁶ TRIP analysis of 2011 Federal Highway Administration data.
- ⁷ Ibid.
- ⁸ Ibid.
- ⁹ TRIP analysis of 2011 Federal Highway Administration data.
- ¹⁰ Ibid.
- ¹¹ Highway Development and Management: Volume Seven. Modeling Road User and Environmental Effects in HDM-4. Bennett, C. and Greenwood, I. 2000.
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- ¹⁴ At The Crossroads: Preserving our Highway Investment, 2005. National Center for Pavement Preservation. P. 5.
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- ¹⁹ Federal Highway Administration, 2010. Beyond the Short Term: Transportation Asset Management for Long-Term Sustainability, Accountability and Performance. Chapter 5.
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- ²¹ Ibid.
- ²² Pothole Repair, FHWA-RD-99-202, Federal Highway Administration, www.tfhr.gov
- ²³ Ibid.
- ²⁴ TRIP estimated based on the 2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, U.S. Department of Transportation. See Exhibit 8-10.
- ²⁵ Ibid.
- ²⁶ Ibid.
- ²⁷ Ibid.
- ²⁸ Federal Highway Administration (2013). FY 2013 and FY 2014 MAP-21 Apportionment tables. <http://www.fhwa.dot.gov/map21/>
- ²⁹ American Association of State Highway and Transportation Officials (2013). Estimated Federal Highway and Transit Program Funding Level With No New Revenues to HTF.
- ³⁰ Federal Highway Administration (2008). Employment Impacts of Highway and Infrastructure Investment. <http://www.fhwa.dot.gov/policy/otps/pubs/impacts/index.htm>
- ³¹ Federal Highway Administration, 2010. Beyond the Short Term: Transportation Asset Management for Long-Term Sustainability, Accountability and Performance.
- ³² Ibid.
- ³³ FHWA estimate based on their analysis of 2008 data. For more information on FHWA's cost-benefit analysis of highway investment, see the 2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance