Bumpy Road Ahead:

AMERICA'S ROUGHEST RIDES AND STRATEGIES TO MAKE OUR ROADS SMOOTHER

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TRIP
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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 surface transportation issues. TRIP is sponsored by insurance companies, equipment manufacturers, distributors and suppliers; businesses involved in highway and transit engineering and construction; labor unions; and organizations concerned with efficient and safe surface transportation.

EXECUTIVE SUMMARY: KEY FACTS ABOUT OUR NATION'S URBAN ROADS

Keeping the wheel steady on America's roads and highways has become increasingly challenging as drivers encounter potholes and pavement deterioration. One-third of the nation's major urban roadways – highways and major streets that are the main routes for commuters and commerce – are in poor condition. These critical links in the nation's transportation system carry 70 percent of the approximately 3.2 trillion miles driven annually in America. Road conditions could deteriorate even further as the rate of vehicle travel continues to increase and local and state governments find they are unable to adequately fund road repairs.

In this report, TRIP examines the condition of the nation's major 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) 2016 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. Following are the major findings of the TRIP report.

THE NATION'S URBAN ROADS ARE INCREASINGLY DETERIORATED

One-third (33 percent) of the nation's major urban roads are rated in poor condition, providing drivers with a rough ride. The charts below detail the top 20 U.S. urban areas with the highest share of major roads in poor condition. The report's Appendix includes pavement condition data for all U.S. urban areas with a population of 200,000 or more.

Rank	Large Urban Areas - 500K+	State	Poor Share	Mid-Sized Urban Areas - 200K-500K	State	Poor Share
1	San Francisco--Oakland, CA	CA	71%	Antioch, CA	CA	57%
2	San Jose, CA	CA	64%	Concord, CA	CA	56%
3	Los Angeles--Long Beach--Anaheim, CA	CA	57%	Madison, WI	WI	49%
4	Milwaukee, WI	WI	54%	Oxnard, CA	CA	48%
5	Honolulu, HI	HI	54%	Round Lake Beach--McHenry--Grayslake, IL--WI	IL-WI	44%
6	Akron, OH	OH	49%	Jackson, MS	MS	44%
7	Cleveland, OH	OH	49%	Santa Rosa, CA	CA	43%
8	New York--Newark, NY--NJ--CT	NY-NJ-CT	46%	Green Bay, WI	WI	43%
9	Providence, RI--MA	RI-MA	46%	Stockton, CA	CA	43%
10	Philadelphia, PA--NJ--DE--MD	PA-NJ-DE-MD	43%	Victorville--Hesperia, CA	CA	42%
11	Seattle, WA	WA	41%	Appleton, WI	WI	41%
12	Sacramento, CA	CA	41%	Santa Clarita, CA	CA	41%
13	Riverside--San Bernardino, CA	CA	40%	Laredo, TX	TX	40%
14	Memphis, TN--MS--AR	TN-MS-AR	40%	Lafayette, LA	LA	40%
15	Bridgeport--Stamford, CT--NY	CT-NY	40%	Lubbock, TX	TX	39%
16	Fresno, CA	CA	40%	Fayetteville--Springdale--Rogers, AR--MO	AR-MO	38%
17	Denver--Aurora, CO	CO	40%	Thousand Oaks, CA	CA	38%
18	Baton Rouge, LA	LA	38%	Canton, OH	OH	38%
19	Colorado Springs, CO	CO	37%	Little Rock, AR	AR	38%
20	Oklahoma City, OK	OK	37%	Modesto, CA	CA	37%

ROUGH URBAN ROADS COME WITH HIGH COSTS TO DRIVERS

The average motorist in the U.S. is losing $599 annually – a total of $130 billion nationally – in additional vehicle operating costs (VOC) as a result of driving on roads in need of repair. These costs include additional repair costs, accelerated vehicle deterioration and depreciation, increased maintenance costs, and additional fuel consumption. The chart below details the top 20 U.S. urban areas (500,000+ population and 200,000-500,000 population) where motorists pay the highest annual vehicle operating costs as a result of driving on rough roads. The report's appendix includes VOC data for all urban areas with a population of 200,000 or more.

Rank	Large Urban Areas - 500K+	State	VOC	Mid-Sized Urban Areas- 200K-500K	State	VOC
1	San Francisco--Oakland, CA	CA	$ 1,049	Jackson, MS	MS	$ 944
2	San Jose, CA	CA	$ 983	Antioch, CA	CA	$ 942
3	Milwaukee, WI	WI	$ 944	Concord, CA	CA	$ 923
4	Los Angeles--Long Beach--Anaheim, CA	CA	$ 921	Madison, WI	WI	$ 910
5	Tulsa, OK	OK	$ 898	Laredo, TX	TX	$ 858
6	Oklahoma City, OK	OK	$ 897	Appleton, WI	WI	$ 855
7	Cleveland, OH	OH	$ 887	Oxnard, CA	CA	$ 852
8	Honolulu, HI	HI	$ 851	Lubbock, TX	TX	$ 801
9	Akron, OH	OH	$ 837	Green Bay, WI	WI	$ 795
10	Riverside--San Bernardino, CA	CA	$ 795	Fayetteville--Springdale--Rogers, AR--MO	AR-MO	$ 782
11	El Paso, TX--NM	TX-NM	$ 788	Santa Clarita, CA	CA	$ 780
12	Baton Rouge, LA	LA	$ 755	Santa Rosa, CA	CA	$ 776
13	Fresno, CA	CA	$ 755	Little Rock, AR	AR	$ 771
14	Sacramento, CA	CA	$ 754	Victorville--Hesperia, CA	CA	$ 768
15	Memphis, TN--MS--AR	TN-MS-AR	$ 746	Thousand Oaks, CA	CA	$ 765
16	Denver--Aurora, CO	CO	$ 739	Lafayette, LA	LA	$ 765
17	Philadelphia, PA--NJ--DE--MD	PA-NJ-DE-MD	$ 732	Stockton, CA	CA	$ 743
18	Detroit, MI	MI	$ 732	Shreveport, LA	LA	$ 727
19	Bridgeport--Stamford, CT--NY	CT	$ 730	South Bend, IN--MI	IN-MI	$ 720
20	Providence, RI--MA	RI-MA	$ 724	Fort Wayne, IN	IN	$ 719

TRAVEL AND POPULATION GROWTH ARE FURTHER STRAINING TRANSPORTATION NETWORK

Vehicle travel in the U.S. increased 16 percent from 2000 to 2016, while the nation's population grew 15 percent from 2000 to 2017. Travel by large commercial trucks increased 29 percent from 2000 to 2016. The additional travel increases the amount of road, highway and bridge investment needed to improve conditions and meet the nation's transportation needs.

A SIGNIFICANT BOOST IN FUNDING IS NEEDED TO IMPROVE ROADWAY CONDITIONS

The U.S. Department of Transportation's (USDOT) semi-annual report on the condition, use and funding needs of the nation's surface transportation program found that the current backlog in needed road and highway rehabilitation is $419.5 billion and that the nation's current $41 billion annual investment in maintaining the condition of roads and highways should be increased by 33 percent to $61 billion annually to improve the condition of America's roads and highways.

TRANSPORTATION INVESTMENT STRENGTHENS THE ECONOMY

The design, construction and maintenance of transportation infrastructure in the U.S. play a critical role in the nation's economy, supporting the equivalent of four million full-time jobs across all sectors of the nation's economy. Approximately 63 million full-time jobs in the U.S. in key industries like tourism, retail sales, agriculture and manufacturing are dependent on the quality, safety and reliability of America's transportation infrastructure network.

INTRODUCTION

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

But, the daily pounding that urban roadways endure from cars and trucks has taken a toll. From coast to coast, major streets and freeways in most U.S. communities are showing significant signs of distress. The result of this increasing stress, coupled with other factors, is that one-third (33 percent) of urban streets and highways have rough pavements that provide a ride that many drivers find unacceptable. 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 require more maintenance, wear out more quickly, and consume more fuel.

This report examines 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. Pavement condition data is 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. The urban areas in the report are defined as the city proper and the surrounding suburban areas.

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

U.S. VEHICLE TRAVEL TRENDS

Increases in vehicle travel since 2000 have resulted in a significant increase in wear and tear on the nation's roads. Vehicle travel growth, which slowed significantly as a result of the Great Recession and subsequent slow economic recovery, has since returned to pre-recession growth rates. From 2000 to 2016, vehicle travel in the U.S. increased by 16 percent.[1] The rate of growth in U.S. vehicle miles of travel has accelerated since 2013, increasing by six percent between 2013 and 2016.[2]

Travel by large commercial trucks, which place significant stress on paved road and highway surfaces, continues to increase at a rate approximately double the rate for all vehicles, and is anticipated to continue to grow at a significant rate through 2030. Travel by large commercial trucks in the U.S. increased by 29 percent from 2000 to 2016.[3] The level of heavy truck travel nationally is anticipated to increase by approximately 56 percent from 2018 to 2045, putting greater stress on the nation's roadways.[4]

U.S. URBAN PAVEMENT CONDITIONS

The pavement data in this report, which is for all urban arterial and collector roads and highways, is provided by the FHWA, based on data submitted annually by state departments of transportation on the condition of major state and locally maintained roads and highways. Pavement data for Interstate highways and other principal arterials is collected for all system mileage, whereas pavement data for minor arterial and all collector roads and highways is based on sampling portions of roadways as prescribed by FHWA to insure the data collected is adequate to provide an accurate assessment of pavement conditions on these roads and highways. The "ride quality" of highways and roadways is typically evaluated using the International Roughness Index (IRI), although some roads were also rated by the Present Serviceability Rating (PSR). While there may be some variance in how

transportation officials apply these indices, the FHWA data are the only national source of pavement condition ratings based on a consistent criterion.

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

Chart 1. Pavement condition rating score, based on IRI and PSR data.

	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 2016 pavement data found that 33 percent of the nation's major urban roads – Interstates, freeways and other major routes – had pavements that were in poor condition.[7] These are roads and highways that provide an unacceptable ride and are in need of resurfacing or more significant repairs. TRIP's analysis of FHWA data from 2016 also found that 25 percent of these major

urban routes were in mediocre condition and 14 percent were in fair condition.[8] The remaining 28 percent of major urban highways and roads were found to provide good ride quality.[9]

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

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

Although road deterioration is often accelerated by freeze-thaw cycles, found most often in the nation's northern and mid-western regions, the urban areas with the highest share of poor pavement conditions include urban areas from a variety of geographic areas.

The chart below details the top 20 large urban areas (population of 500,000 or above) with the highest percentage of major roadways that provide poor ride quality, in order of rank. The report Appendix includes the share of pavement in poor, mediocre, fair and good condition for all U.S. urban areas over 500,000 population.

Chart 2. Large urban areas (500,000+ population) with highest share of major roads and highways in poor condition.

Rank	Large Urban Areas - 500K+	State	Poor Share
1	San Francisco--Oakland, CA	CA	71%
2	San Jose, CA	CA	64%
3	Los Angeles--Long Beach--Anaheim, CA	CA	57%
4	Milwaukee, WI	WI	54%
5	Honolulu, HI	HI	54%
6	Akron, OH	OH	49%
7	Cleveland, OH	OH	49%
8	New York--Newark, NY--NJ--CT	NY-NJ-CT	46%
9	Providence, RI--MA	RI-MA	46%
10	Philadelphia, PA--NJ--DE--MD	PA-NJ-DE-MD	43%
11	Seattle, WA	WA	41%
12	Sacramento, CA	CA	41%
13	Riverside--San Bernardino, CA	CA	40%
14	Memphis, TN--MS--AR	TN-MS-AR	40%
15	Bridgeport--Stamford, CT--NY	CT-NY	40%
16	Fresno, CA	CA	40%
17	Denver--Aurora, CO	CO	40%
18	Baton Rouge, LA	LA	38%
19	Colorado Springs, CO	CO	37%
20	Oklahoma City, OK	OK	37%

Source: TRIP analysis of FHWA data.

The chart below details the top 20 mid-sized urban areas (population of 200,000-500,000) with the highest percentage of major roadways that provide poor ride quality, in order of rank. The report Appendix includes the share of pavement in poor, mediocre, fair and good condition for all U.S. urban areas with population between 200,000-500,000.

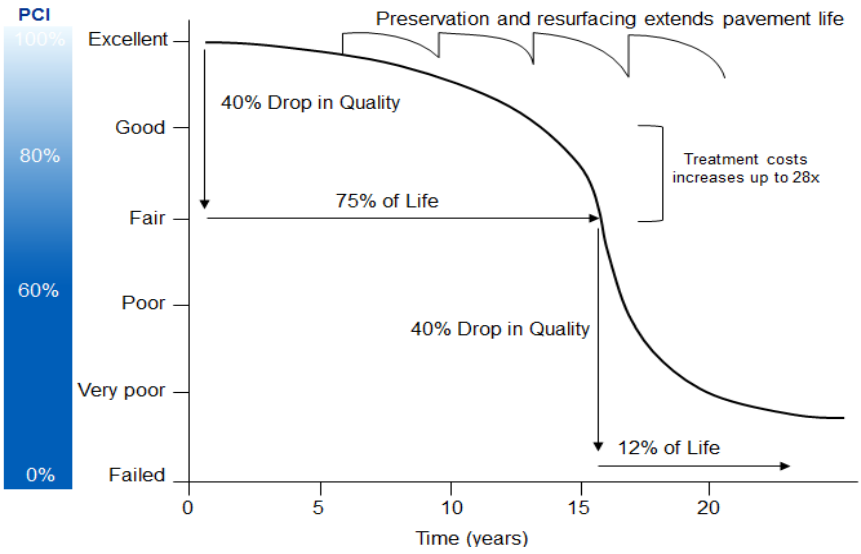
Chart 3. Mid-sized urban areas (200,000-500,000 population) with highest share of major roads and highways in poor condition.

Rank	Mid-Sized Urban Areas - 200K-500K	State	Poor Share
1	Antioch, CA	CA	57%
2	Concord, CA	CA	56%
3	Madison, WI	WI	49%
4	Oxnard, CA	CA	48%
5	Round Lake Beach--McHenry--Grayslake, IL-	IL	44%
6	Jackson, MS	MS	44%
7	Santa Rosa, CA	CA	43%
8	Green Bay, WI	WI	43%
9	Stockton, CA	CA	43%
10	Victorville--Hesperia, CA	CA	42%
11	Appleton, WI	WI	41%
12	Santa Clarita, CA	CA	41%
13	Laredo, TX	TX	40%
14	Lafayette, LA	LA	40%
15	Lubbock, TX	TX	39%
16	Fayetteville--Springdale--Rogers, AR--MO	AR	38%
17	Thousand Oaks, CA	CA	38%
18	Canton, OH	OH	38%
19	Little Rock, AR	AR	38%
20	Modesto, CA	CA	37%

Source: TRIP analysis of FHWA data.

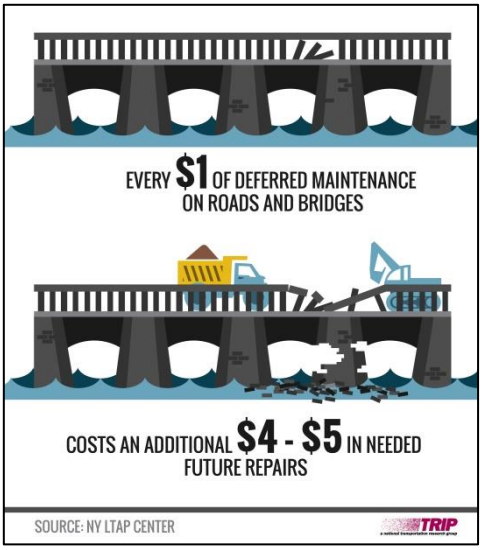
Pavement failure is caused by a combination of traffic, moisture and climate. Moisture often works its way into road surfaces and the materials that form the road's foundation. Road surfaces at intersections are more prone to deterioration because the slow-moving or standing loads occurring at these sites subject the pavement to higher levels of stress. It is critical that roads are fixed before they require major repairs because reconstructing roads costs approximately four times more than resurfacing them.[10] As roads and highways continue to age, they will reach a point of deterioration where routine paving and maintenance will not be adequate to keep pavement surfaces in good condition and costly reconstruction of the roadway and its underlying surfaces will become necessary.

Chart 4. Pavement Condition Cycle Time with Treatment and Cost



Source: North Carolina Department of Transportation (2016). 2016 Maintenance Operations and Performance Analysis Report

Long-term repair costs increase significantly when road and bridge maintenance is deferred, as road and bridge deterioration accelerates later in the service life of a transportation facility and requires more costly repairs. A report on maintaining pavements found that every $1 of deferred maintenance on roads and bridges costs an additional $4 to $5 in needed future repairs.[11]



THE COST TO MOTORISTS OF ROADS IN INADEQUATE CONDITION

TRIP has calculated the additional cost to motorists of driving on roads in poor, mediocre or fair condition. When roads are in poor, mediocre or fair condition – which may include potholes, rutting or rough surfaces – the cost to operate and maintain a vehicle increases. These additional vehicle operating costs (VOC) include accelerated vehicle depreciation, additional vehicle repair costs, increased fuel consumption and increased tire wear.

Additional vehicle operating costs have been calculated in the Highway Development and Management Model (HDM), which is recognized by the U.S. Department of Transportation and 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.[12] The HDM study found that road deterioration increases ownership, repair, fuel and tire costs. The report found that deteriorated roads accelerate the pace of 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.

TRIP's additional VOC estimate is based on taking the average number of miles driven annually by a motorist, calculating current VOC based on AAA's 2017 VOC and then using the HDM model to estimate the additional VOC paid by drivers as a result of substandard roads.[13] Additional research on the impact of road conditions on fuel consumption by the Texas Transportation Institute (TTI) is also factored in to TRIP's vehicle operating cost methodology.

TRIP estimates that driving on roads in need of repair costs the average driver $599 annually in extra vehicle operating costs - $130 billion nationwide. Individual driver operating costs may be somewhat higher or lower depending on the amount of travel by an individual driver and the type of vehicle driven, as larger vehicles tend to have greater increases in operating costs due to substandard roads.

The chart below details the large urban areas (population of 500,000 or more) with the highest annual additional vehicle operating cost per driver as a result of driving on rough roads. The report's Appendix includes vehicle operating costs for all U.S. urban areas with a population of 500,000 or more.

Chart 5. Large urban areas (500,000+ population) with the highest per-driver vehicle operating costs due to rough roads.

Rank	Large Urban Areas - 500K+	State	VOC
1	San Francisco--Oakland, CA	CA	$ 1,049
2	San Jose, CA	CA	$ 983
3	Milwaukee, WI	WI	$ 944
4	Los Angeles--Long Beach--Anaheim, CA	CA	$ 921
5	Tulsa, OK	OK	$ 898
6	Oklahoma City, OK	OK	$ 897
7	Cleveland, OH	OH	$ 887
8	Honolulu, HI	HI	$ 851
9	Akron, OH	OH	$ 837
10	Riverside--San Bernardino, CA	CA	$ 795
11	El Paso, TX--NM	TX-NM	$ 788
12	Baton Rouge, LA	LA	$ 755
13	Fresno, CA	CA	$ 755
14	Sacramento, CA	CA	$ 754
15	Memphis, TN--MS--AR	TN-MS-AR	$ 746
16	Denver--Aurora, CO	CO	$ 739
17	Philadelphia, PA--NJ--DE--MD	PA-NJ-DE-MD	$ 732
18	Detroit, MI	MI	$ 732
19	Bridgeport--Stamford, CT--NY	CT	$ 730
20	Providence, RI--MA	RI-MA	$ 724

Source: TRIP analysis.

The chart below details the mid-sized urban areas (population of 200,000 to 500,000) with the highest annual additional vehicle operating cost per driver as a result of driving on rough roads. The report's Appendix includes vehicle operating costs for all U.S. urban areas with a population of 200,000-500,000.

Chart 6. Mid-sized urban areas (200,000-500,000 population) with the highest per-driver vehicle operating costs due to rough roads.

Rank	Mid-Sized Urban Areas - 200K-500K	State	VOC
1	Jackson, MS	MS	$ 944
2	Antioch, CA	CA	$ 942
3	Concord, CA	CA	$ 923
4	Madison, WI	WI	$ 910
5	Laredo, TX	TX	$ 858
6	Appleton, WI	WI	$ 855
7	Oxnard, CA	CA	$ 852
8	Lubbock, TX	TX	$ 801
9	Green Bay, WI	WI	$ 795
10	Fayetteville--Springdale--Rogers, AR--MO	AR	$ 782
11	Santa Clarita, CA	CA	$ 780
12	Santa Rosa, CA	CA	$ 776
13	Little Rock, AR	AR	$ 771
14	Victorville--Hesperia, CA	CA	$ 768
15	Thousand Oaks, CA	CA	$ 765
16	Lafayette, LA	LA	$ 765
17	Stockton, CA	CA	$ 743
18	Shreveport, LA	LA	$ 727
19	South Bend, IN--MI	IN	$ 720
20	Fort Wayne, IN	IN	$ 719

Source: TRIP analysis.

THE LIFECYCLE OF PAVEMENT

Paved roadway surfaces are considered to have five stages in their life cycle. Each of these stages has a significant impact on the smoothness of the road surface.[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 performance of the pavement surface. The second stage is the actual construction or reconstruction of the road or highway surface. The quality of the construction process has a significant impact on the longevity of the pavement surface. The third stage is the first few years in use when a roadway surface starts to experience some initial deterioration as a result of traffic volume, rain, snow, solar radiation and temperature changes. At this stage, a road surface appears to still be in good condition and

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

Chart 7. 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.

STRATEGIES FOR A SMOOTHER ROAD

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.[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 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.[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 (NCPP), ***At the Crossroads: Preserving our Highway Investment,*** recommended that transportation agencies adopt a pavement preservation strategy for the maintenance of the nation's roads and highways.[17] Instead of a reactive

approach to roadway pavement maintenance that provides repairs to the road surfaces in the worst condition, the book recommends using a proactive approach that provides initial maintenance to pavements still in good condition, to significantly delay the need for costly reconstruction.

The NCPP book noted that preventive maintenance can only be performed on road surfaces that are structurally sound. All other road and highway surfaces first need to be reconstructed before a preventive maintenance approach will be effective. The book recommends that transportation agencies implement a preventive maintenance program for roads and highways that are structurally sound and in good condition. It also suggests that transportation agencies should continue to make surface repairs to roads and highways that are not structurally sound to maintain them in reasonable condition until there is adequate funding for the reconstruction of these roads, at which point transportation agencies can then implement a preventive maintenance program for these improved roads.[18]

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.[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 have been developed since then that can be tailored to the individual requirements of various sections of roads and highways, including high performance concrete pavements and improved hot- and warm-mix asphalt pavements. Some pavement designs now call for varying material compositions in different pavement layers and thicker bottom layers, which resist bottom-up cracking and provide a sturdier base for the top layer of pavement, which can be resurfaced periodically.[21]

EFFECTIVE POTHOLE PATCHING

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

The FHWA studied a variety of pothole patching techniques to determine the best practice. The study was based on assessing 1,250 pothole patches at eight locations under varying weather conditions over a four-year period. The study found that 56 percent of the patches were still functioning by the end of the study period.[22] 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.[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 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 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 2015 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance, found that the nation has a significant backlog in needed road and highway rehabilitation and would need a large boost in investment to improve the condition of the nation's roads and highways.

The USDOT report estimates that the current backlog in needed road and highway rehabilitation is $419.5 billion.[24] The report found that the current level of investment in preserving roads and highways is inadequate to improve the condition of the nation's roadways. The U.S. DOT report found that the nation current $41 billion annual investment in maintaining the condition of roads and highways by all levels of government should be increased by 33 percent to $61 billion annually to improve the condition of the nation's roads and highways.[25]

TRANSPORTATION AND ECONOMIC GROWTH

Today's culture of business demands that an area have well-maintained and efficient roads, highways and bridges if it is to remain economically competitive. Global communications and the impact of free trade in North America and elsewhere have resulted in a significant increase in freight movement, making the quality of a region's transportation system a key component in a business's ability to compete locally, nationally and internationally.

Businesses have responded to improved communications and the need to cut costs with a variety of innovations including just-in-time delivery, increased small package delivery, demand-side inventory management and e-commerce. The result of these changes has been a significant

improvement in logistics efficiency as firms move from a push-style distribution system, which relies on large-scale warehousing of materials, to a pull-style distribution system, which relies on smaller, more strategic movement of goods. These improvements have made mobile inventories the norm, resulting in the nation's trucks literally becoming rolling warehouses.

Highways are vitally important to continued economic development in the United States. As the economy expands, creating more jobs and increasing consumer confidence, the demand for consumer and business products grows. In turn, manufacturers ship greater quantities of goods to market to meet this demand, a process that adds to truck traffic on the nation's highways and major arterial roads.

Every year, $28 trillion in goods are shipped to and from sites in the U.S., mostly by trucks.[26] Seventy-three percent of the goods shipped annually to and from sites in the U.S. are carried by trucks and another 14 percent are carried by courier services or multiple-mode deliveries, which include trucking.[27]

The design, construction and maintenance of transportation infrastructure in the U.S. play a critical role in the nation's economy, supporting the equivalent of four million full-time jobs across all sectors, earning these workers approximately $156 billion annually.[28] These jobs include two million full-time jobs directly involved in transportation infrastructure construction and related activities. Spending by employees and companies in the transportation design and construction industry support an additional two million full-time jobs.[29]

Transportation construction in the U.S. contributes an estimated $28.4 billion annually in state and local income, corporate and unemployment insurance taxes and the federal payroll tax.[30]

Approximately 63 million full-time jobs in the U.S. in key industries like tourism, retail sales, agriculture and manufacturing are dependent on the quality, safety and reliability of America's transportation infrastructure network. These workers earn $2.5 trillion in wages and contribute an

estimated $462 billion in state and local income, corporate and unemployment insurance taxes and the federal payroll tax.[31]

Local, regional and state economic performance is improved when a region's surface transportation system is expanded or repaired. This improvement comes as a result of the initial job creation and increased employment created over the long-term because of improved access, reduced transport costs and improved safety.

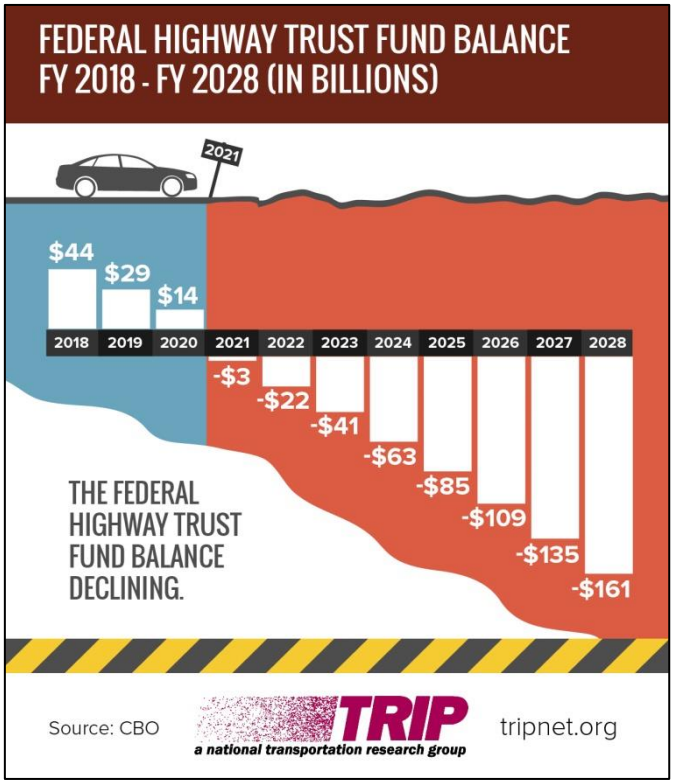
Increasingly, companies are looking at the quality of a region's transportation system when deciding where to re-locate or expand. Regions with congested or poorly maintained roads may see businesses relocate to areas with a smoother, more efficient and more modern transportation system. Highway accessibility was ranked the number one site selection factor in a 2017 survey of corporate executives by Area Development Magazine. Labor costs and the availability of skilled labor, which are both impacted by a site's level of accessibility, were rated second and third, respectively.[32]

TRANSPORTATION FUNDING

Investment in the nation's roads, highways and bridges is funded by local, state and federal governments. A lack of sufficient funding at all levels will make it difficult to adequately maintain and improve America's existing transportation system.

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

Most federal funds for highway and transit improvements are provided by federal highway user fees, largely an 18.4 cents-per-gallon tax on gasoline and a 24.4 cents-per-gallon tax on diesel fuel. Since 2008 revenue into the federal Highway Trust Fund has been inadequate to support legislatively set funding levels so Congress has transferred approximately $53 billion in general funds and an additional $2 billion from a related trust fund into the federal Highway Trust Fund.[33]



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

The five-year, $305 billion FAST Act will provide a boost of approximately 15 percent in highway funding and 18 percent in transit funding over the duration of the program, which expires in 2020.[34] In addition to federal motor fuel tax revenues, the FAST Act will also be funded by $70 billion in U.S. general funds, which will rely on offsets from several unrelated federal programs including the Strategic Petroleum Reserve, the Federal Reserve and U.S. Customs.

President Trump's infrastructure plan, released in February 2018, would provide $200 billion in new federal grants and loans over 10 years to leverage $1.5 trillion in total project spending on infrastructure, including surface transportation. State and local governments and the private sector

would be required to raise the additional $1.3 trillion to access the federal grants and loans provided under this initiative. Congress has not yet crafted a transportation program in response to the Trump proposal and would need to identify a long-term, sustainable source of funding to support increased funding for the federal Highway Trust Fund.

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.

# # #

ENDNOTES

[1] Federal Highway Administration (2016). Highway Statistics 2000, 2013, 2016 VM-1.
[2] Ibid.
[3] Federal Highway Administration (2016). Highway Statistics 2000, 2016, VM-1.
[4] TRIP analysis of the Federal Highway Administration Freight Analysis Framework Tabulation Tool. https://faf.ornl.gov/faf4/Extraction1.aspx Data is for total truck ton-miles. http://bottomline.transportation.org/Documents/Bottom%20Line%202015%20Executuve%20Version%20FINAL.pdf
[5] 2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, U.S. Department of Transportation. Exhibit 3-1.
[6] A Statistical Analysis of Factors Associated With Perceived Road Roughness by Drivers, K. Shafizadeh, University of Washington, F. Mannering, Purdue University, (2002).
[7] TRIP analysis of 2016 Federal Highway Administration data, 2016 Highway Statistics, HM-63, HM-64.
[8] Ibid.
[9] Ibid.
[10] Selecting a Preventative Maintenance Treatment for Flexible Pavements. R. Hicks, J. Moulthrop. Transportation Research Board. 1999. Figure 1.
[11] Pavement Maintenance, by David P. Orr, PE Senior Engineer, Cornell Local Roads Program, March 2006.
[12] Highway Development and Management: Volume Seven. Modeling Road User and Environmental Effects in HDM-4. Bennett, C. and Greenwood, I. 2000.
[13] Your Driving Costs. American Automobile Association. 2017.
[14] At The Crossroads: Preserving our Highway Investment, 2005. National Center for Pavement Preservation. P. 5.
[15] T. Kuennen, Better Roads, March 2003. New Technologies Boost Pavement Smoothness. P. 37.
[16] Galehouse, L., Moulthrop, J., Hicks, G. Principles of Pavement Preservation, TR News, October 2003. P. 6-7. Transportation Research Board.
[17] At the Crossroads: Preserving Our Nation's Highway Investment, 2005. National Center for Pavement Preservation.
[18] Ibid. P. 31.
[19] Federal Highway Administration, 2010. Beyond the Short Term: Transportation Asset Management for Long-Term Sustainability, Accountability and Performance. Chapter 5.
[20] Transportation Research Board, 2005. Performance By Design: Final Report of TRB Superpave Committee. P. 1.
[21] Ibid.
[22] Pothole Repair, FHWA-RD-99-202, Federal Highway Administration, www.tfhrc.gov
[23] Ibid.
[24] U.S. Department of Transportation (2017). 2015 Status of the Nation's Highways, Bridges, nd Transit: Conditions and Performance, U.S. Department of Transportation. Exhibit 8.4.
[25] U.S. Department of Transportation (2017). 2015 Status of the Nation's Highways, Bridges, nd Transit: Conditions and Performance, U.S. Department of Transportation. Exhibit 8.5.
[26] TRIP analysis of Bureau of Transportation Statistics, U.S. Department of Transportation. 2012 Commodity Flow Survey, State Summaries.
[27] Ibid.
[28] American Road & Transportation Builders Association (2015). The 2015 U.S. Transportation Construction Industry Profile. https://www.transportationcreatesjobs.org/pdf/Economic_Profile.pdf
[29] Ibid.
[30] Ibid
[31] Ibid.

[32] Area Development Magazine (2018). 32nd Annual Survey of Corporate Executives: Availability of Skilled Labor New Top Priority. http://www.areadevelopment.com/Corporate-Consultants-Survey-Results/Q1-2018/32nd-annual-corporate-survey-14th-annual-consultants-survey.shtml

[33] "Surface Transportation Reauthorization and the Solvency of the Highway Trust Fund," presentation by Jim Tymon, American Association of State Highway and Transportation Officials (2014).

[34] 2015 "Fixing America's Surface Transportation Act." (2015) American Road and Transportation Builders Association. http://www.artba.org/newsline/wp-content/uploads/2015/12/ANALYSIS-FINAL.pdf