PSOMAS

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Registered Professional Engineer (Civil)
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ARIZONA U.S.A.
EXPIRES 9/30/17

MEMO

To: Foothills Clusters Home Owners Association (FCHOA)

From: Heidi Lasham PE, ENV SP

Date: March 9, 2016

Subject: FCHOA 2015 Roads Rehabilitation/ Renovation Project

This memo is in response to our meeting with the FCHOA Streets Committee on August 6, 2015. During this meeting Psomas was requested to assess the costs and benefits of various pavement repair options. As part of our services we commissioned a soils report and completed a pavement design. This work was intended to identify any major subgrade failures and recommend how to address them prior to placing new pavement, to help insure an adequate design life from the new pavement. Depending on the options ultimately chosen by the Association, Psomas would be willing to offer our services to oversee the construction activities to ensure that FCHOA is receiving the proper materials, appropriate testing and top quality construction.

The pavement options that will be evaluated are:

- Option 1. Double chip seal, followed by single chip seal in 2019, and by reconstruction in 2022.
- Option 2. Overlay 1-1/2"on existing pavement, followed by reconstruction in 2025.
- Option 3. Remove, dispose of existing asphalt pavement and recompact native soil (subgrade prior to paving). Then pave with 2.5 inches of Tucson Department of Transportation (TDOT) Mix #2 (Local Streets).
- Option 4. Pulverize existing asphalt pavement (blend with existing native soil subgrade to form 8" subbase). Then recompact soil (subbase) to proposed grades (no export of material) and pave with 2.5 inches of TDOT Mix #2 (Local Streets).
- Option 5. Green Asphalt – Tucson Asphalt proprietary product

Below will be further discussions on the above options.

In the various options there are references to VOC (Vehicle Operating Costs), which estimate the extra annual cost to operate a vehicle on poorly maintained roadways. The amount of VOC above the national average for drivers in the Tucson region is $723. This figure was extracted from "Bumpy Roads Ahead: America's Roughest Rides and Strategies to Make our Roads Smoother" (dated October 3, 2013), a research report developed by TRIP, a prominent national transportation research group. This report is attached to this memo in the Appendix D.

We understand that not all the driving is done on your privately owned roadways so we have prorated the VOC of $723 as follows:

- The average trip is estimated at 10 miles
- Annual average miles driven is estimated at 10,000 miles.
- The average miles per round-trip on FCHOA streets is approximately 2 miles or 20% of all miles driven.
- Therefore, the extra costs attributed to the bad roads of FCHOA is $723 times 20% which equals $145 per year in vehicle maintenance costs. There's 367 homes within FCHOA and it's assumed that each household has two (2) vehicles, bringing the annual neighborhood cost of driving on failed roadway surfaces to $106,430.
- Assumptions have also been made as to the relatively lower operating costs of less severely damaged streets, in order to establish a fair comparison among the various options over their lives, reflecting various levels of roughness over time.

Do nothing

This scenario doesn't cost anything to the FCHOA however it creates accelerated maintenance costs on vehicles which is an added cost to each homeowner. This scenario will buy additional time if needed to acquire additional funding for the desired option. The pavement will continue to deteriorate and crumble during this time period.

Option 1: Double chip seal

This option doesn't address the pavement damage that has occurred. Within approximately three to five years you will be back where you are today. The cracks that you see today will resurface shortly after the double chip seal has been performed and the ride quality will not improve. Crack sealing in some magnitude will be needed on an annual basis until full replacement of the pavement is performed (Options 3 or 4). Therefore, VOC's of $145 per vehicle per year are incurred starting at year one. VOC's will accrue and crack sealing will be performed annually as a result of the reflective cracking. Then after year 5, a full replacement of the roadway, Options 3 or 4, will be required.

Cost: Approximately $0.85 / Sq. Yd. for Single Chip Seal and $1.70/ Sq. Yd. for Double Chip Seal, VOC's are $145 per vehicle per year. The cost of permits or inspection services is not included in the overall cost. Over a 30 year period FCHOA is looking at a cost of approximately $2,059,100.

Note: time frames for maintenance may be adjusted due to the annual inspections performed by the FCHOA streets committee and the performance of the roadways.

Option 2: Overlay 1-1/2" on existing pavement

This option will improve the ride quality for the first five years and reflective cracking will begin to occur between 3 to 5 years after 1-1/2" overlay is constructed. The year after the overlay is constructed, a fog coat should be placed on the pavement. Starting in year three and every year thereafter until the roadway is rebuilt (Options 3 or 4), VOC's are incurred annually. In year 4 crack sealing will be needed. In year 5 a slurry seal should be placed on the pavement. In years 6 through 8 crack sealing is performed annually. As noted above the VOC's begin in year three and as the pavement deteriorates the VOC's increase indicating the pavement is returning to the state it is in today and in year 9 a full replacement (Options 3 or 4) of the roadway is needed. Utility adjustment costs are included in the cost and estimated off old engineering drawings received from the FCHOA Streets Committee at our last meeting on January 11, 2016. This would include 50 sewer manholes, 30 water valves and 35 communication boxes that will require adjusting.

Cost: Approximately $7.00 / Sq.Yd.

VOC's begin at zero and end up at $145 per vehicle per year as shown in the attached spreadsheet. Utility adjustments are added to this cost, as follows: water valve adjustment is estimated at $250 each, sewer manhole adjustment is estimated at $450 each, and communication adjustment is estimated at $200 each. This options will require permits and inspections which are not included in the above cost per square yard. Over a 30 year period FCHOA is looking at a cost of approximately $2,070,400 for this option.

Note: time frames for maintenance may be adjusted due to the annual inspections performed by the FCHOA streets committee and the performance of the roadways.

Option 3: Remove, dispose of existing asphalt pavement and recompact native soil (subgrade prior to paving). Then pave with 2.5 inches of Tucson Department of Transportation (TDOT) Mix #2 (Local Streets).

This option and Option 4 are approximately equivalent in structure quality. Performing a complete replacement will give you a pavement design life of 20 years but with proper maintenance FCHOA should be able to achieve 30 or more years of pavement life. This option (#3) will keep the pavement at the current elevations, avoiding utility modification expenses. However, itwill have additional cost of trucking due to the export of the old existing pavement.

As you will see in the geotechnical report with testing results (Appendix A), there were several test holes that recorded "refusal" around 1 foot or so in depth. What this means is that the drill rig hit something such as a boulder or cobble and couldn't continue to drill. This is important information, as it warns of a potential increase in subgrade preparation costs due to the need to remove boulders underground and fill in and compact the holes after the boulders are removed.

At year 1 a fog seal application is recommended to preserve the newly placed asphalt. At years 5, 15, and 25 crack seal is applied and then at years 10 and 20 crack seal and a slurry seal should be applied as part of the maintenance of the roadway. This analysis assumes that at year 30 a full depth reconstruction would be required; however as stated above, with the proper maintenance and yearly inspections of the roadways, it's possible to extend the replacement time frame further out.

VOC's will begin in year 12 and continue to increase as the pavement continues to deteriorate as shown in the attached spreadsheet.

Cost: Approximately $11.70 / Sq.Yd.

This price doesn't include additional costs for disposal of the removed pavement, any unforeseen removal of boulders or construction management costs. We suggest going out to bid to get the most competitive price possible. Through the bidding process you will also gain the knowledge of whether it's more cost effective to export the existing pavement or to pulverize it and mix it into the existing subgrade (Option 4). Over a 30 year period FCHOA is looking at a cost of approximately $1,802,400.

Note: time frames for maintenance may be adjusted due to the annual inspections performed by the FCHOA streets committee and the performance of the roadways.

Option 4: Pulverize existing asphalt pavement (blend with existing native soil subgrade to form 8" subbase). Then recompact soil (subbase) to proposed grades (no export of material) and pave with 2.5 inches of TDOT Mix #2 (Local Streets). This option and Option 3 are approximately equivalent in structure quality. Performing a complete replacement will give you a pavement design life of 20 years, but with proper maintenance FCHOA may be able to achieve 30 or more years of pavement life. This option would raise the pavement elevations and introduce additional items to consider such as: feathering the pavement at intersections and driveways, and utility and survey monument adjustments to avoid their burial by the deeper pavement section.

As you will see in the testing results (Appendix A), there were several test holes that recorded "refusal" around 1 foot or so in depth. What this means is that the drill rig hit something such as a boulder and couldn't continue to drill. This is important information, as it warns of a potential increase in subgrade preparation costs due to the need to remove boulders underground and fill in and compact the holes.

Utility adjustment costs are included in the cost and estimated off old engineering drawings received from the FCHOA Streets Committee at our last meeting on January 11, 2016. This would include 50 sewer manholes, 30 water valves and 35 communication boxes that will require adjusting.

At year 1 a fog seal application is suggested to preserve the newly placed asphalt. At years 5, 15, and 25 crack seal is applied and then at years 10 and 20 would have crack seal and a slurry seal applied as part of the maintenance of the roadway. Assumed at year 30 would require a full depth reconstruction however as stated above with the proper maintenance and yearly inspections of the roadways it's possible to extend the replacement time frame further out.

VOC's will begin in year 12 and continue to increase as the pavement continues to deteriorate as shown in the attached spreadsheet.

Cost: Approximately $13.95 / Sq.Yd.

Utility adjustments are included in this cost at the following estimated costs: water valve adjustment is estimated at $250 each, sewer manhole adjustment is estimated at $450 each, and communication adjustment is estimated at $200 each. This price doesn't include possible unforeseen cost for the removal of boulders or construction management costs. We suggest going out to bid to get the most competitive price possible. Through the bidding process you will also gain the knowledge of whether it's more cost effective to export the existing pavement (Option 3) or to pulverize it and mix it into the existing subgrade. Over a 30-year period FCHOA is looking at a cost of approximately $1,944,700.

Note: time frames for maintenance may be adjusted due to the annual inspections performed by the FCHOA streets committee and the performance of the roadways.

Option 5: Green Asphalt – Tucson Asphalt proprietary product

This is a product that had been suggested by the FCHOA for consideration. We could find no engineering analysis performed on it and therefore we are hesitant to comment on the quality of this product. Knowing that the existing pavement structure is failed; we do not advise placing it as an overlay. If you decide to utilize the product, we will help you work with the manufacturer to ensure sufficient warranties are received. For your information a Green Asphalt pamphlet has been added to Appendix C.

Note: time frames for maintenance may be adjusted due to the annual inspections performed by the FCHOA streets committee and the performance of the roadways.

The below table shows all the options compared to one another within a 30 year period with the assumptions considered below the table (prices below are rounded to the nearest $100 dollars).

Year	Option 1: Double Chip Seal			Option 2: 1-1/2" Overlay with Utility Adjustments			Option 3: Remove and Replace 2-1/2" AC			Option 4: Pulverize and Replace 2-1/2" AC			Option 5: Green Asphalt (no Report)
	$1.70 /SY			$7.00 /SY			$11.70 /SY			$13.95 /SY			
	VOC #	VOC cost	Cost w/o VOC	VOC #	VOC cost	Cost w/o VOC	VOC #	VOC cost	Cost w/o VOC	VOC #	VOC cost	Cost w/o VOC	
2016	4	$ 106,500	$ 86,700	1	$ -	$ 371,800	1	$ -	$ * 547,900	1	$ -	$ * 690,200	$ -
2017	4	$ 106,500	$ 7,100	1	$ -	$ 14,100	1	$ -	$ 14,100	1	$ -	$ 14,100	$ -
2018	4	$ 106,500	$ 7,100	2	$ 25,700	$ -	1	$ -	$ -	1	$ -	$ -	$ -
2019	4	$ 106,500	$ 46,900	2	$ 25,700	$ 7,100	1	$ -	$ -	1	$ -	$ -	$ -
2020	4	$ 106,500	$ 7,100	3	$ 66,100	$ 126,500	1	$ -	$ -	1	$ -	$ -	$ -
2021	1	$ -	$ * 547,900	3	$ 66,100	$ 7,100	1	$ -	$ 7,100	1	$ -	$ 7,100	$ -
2022	1	$ -	$ 14,100	4	$ 106,500	$ 7,100	1	$ -	$ -	1	$ -	$ -	$ -
2023	1	$ -	$ -	4	$ 106,500	$ 7,100	1	$ -	$ -	1	$ -	$ -	$ -
2024	1	$ -	$ -	1	$ -	$ * 547,900	1	$ -	$ -	1	$ -	$ -	$ -
2025	1	$ -	$ -	1	$ -	$ 14,100	1	$ -	$ 133,500	1	$ -	$ 133,500	$ -
2026	1	$ -	$ 7,100	1	$ -	$ -	1	$ -	$ -	1	$ -	$ -	$ -
2027	1	$ -	$ -	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2028	1	$ -	$ -	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2029	1	$ -	$ -	1	$ -	$ 7,100	2	$ 25,700	$ 7,100	2	$ 25,700	$ 7,100	$ -
2030	1	$ -	$ 133,500	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2031	1	$ -	$ -	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2032	2	$ 25,700	$ -	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2033	2	$ 25,700	$ -	1	$ -	$ 133,500	2	$ 25,700	$ 133,500	2	$ 25,700	$ 133,500	$ -
2034	2	$ 25,700	$ 7,100	1	$ -	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2035	2	$ 25,700	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2036	2	$ 25,700	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	2	$ 25,700	$ -	$ -
2037	2	$ 25,700	$ -	2	$ 25,700	$ 7,100	2	$ 25,700	$ 7,100	2	$ 25,700	$ 7,100	$ -
2038	2	$ 25,700	$ 133,500	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2039	2	$ 25,700	$ -	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2040	2	$ 25,700	$ -	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2041	2	$ 25,700	$ -	2	$ 25,700	$ 133,500	3	$ 66,100	$ 133,500	3	$ 66,100	$ 133,500	$ -
2042	3	$ 66,100	$ 7,100	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2043	3	$ 66,100	$ -	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2044	3	$ 66,100	$ -	2	$ 25,700	$ -	3	$ 66,100	$ -	3	$ 66,100	$ -	$ -
2045	3	$ 66,100	$ -	2	$ 25,700	$ 7,100	3	$ 66,100	$ 7,100	3	$ 66,100	$ 7,100	$ -
Totals:		**$ 1,053,900**	**$ 1,005,200**		**$ 679,300**	**$ 1,391,100**		**$ 811,500**	**$ 990,900**		**$ 811,500**	**$ 1,133,200**	**$ -**
		$2,059,100			**$2,070,400**			**$1,802,400**			**$1,944,700**		

Assumptions:
Estimate is in 2015 dollars
$145 Vehicle Operation Costs per year per car
Assumed 2 cars per home.
FCHOA has 367 homes.

1	VOC Good = $0 per year per vehicle on FCHOA Roadways = $0/ yr
2	VOC Fair = $35 per year per vehicle on FCHOA Roadways = $25,700/ yr
3	VOC Mediocre = $90 per year per vehicle on FCHOA Roadways = $66,100/ yr
4	VOC Poor = $145 per year per vehicle on FCHOA Roadways = $106,500/ yr

*The dollar amount in the red indicates the need for complete reconstruction of the roadways.
The above costs do not include any boulder removals, if needed.

In Summary costs for all options are estimated construction costs ONLY and do not include design, bidding or construction management services. In reviewing various pavement manuals and the current state of the FCHOA pavement Psomas recommends that you perform a total reconstruction (Options 3 or 4). Please review this material and ask any questions you may have. Once FCHOA is satisfied that the presented options reflect the FCHOA objectives, we recommend that the board take options 3 and 4 out to bid in a competitive bid process. We would be happy to help in the bidding process with all the necessary components to create clarity for bidders and to help you analyze the resultant bids.

The use of the Tucson Department of Transportation (TDOT) Mix #2 (Local Streets) is recommended for your lightly-traveled streets as this mix decreases the amount of air voids by increasing the oil content resulting in a pavement that resists the inevitable oxidation process (how asphalt pavements eventually deteriorate).

FCHOA Maintenance and Rehabilitation Program: The combined effects of traffic loading and the environment will cause every pavement, no matter how well-designed/ constructed to deteriorate over time. Periodic maintenance and rehabilitation are necessary to slow down or reset this deterioration process. Maintenance actions, such as crack sealing, fog seals and patching will help slow down the rate of deterioration by identifying and addressing specific pavement deficiencies that contribute to overall deterioration. Rehabilitation is the act of repairing portions of an existing pavement to reset the deterioration process.

In Appendix B you will see a graphic illustration of the life cycle of pavement and what doing regular maintenance/ rehabilitation on a roadway can do to extend pavement life.

The FCHOA Streets Committee should review the streets on an annual basis to look for signs of deterioration, which will dictate when the needed maintenance is to begin. Such signs include small cracks. Cracks are an easy access point for moisture to make its way through to the subgrade. The goal is to keep moisture out of the subgrade as that will begin to break down the pavement structure and advance the deterioration process. Once cracks are large enough they shall be treated with a crack sealant to protect and extend the life of your pavement.

For FCHOA maintenance budgeting purposes, on the next page, is a table showing the various maintenance options and approximate costs associated with those repairs in today’s (2015) dollars.

Potential Maintenance Treatment Options:	**SY of Pavement**	**Cost per SY**	**Total Cost (in 2015 $)**
Annual Pothole repairs (based on 2015 repairs of 16 Tons used at $790.78 per ton = $12,652)			**$12,652**
Single Chip Seal	46,824	$0.85	**$39,800.40**
Double Chip Seal	46,824	$1.70	**$79,600.80**
Overlay 1-1/2"	46,824	$7.00	**$327,768.00**
Crack Seal	46,824	$0.15	**$7,100**
Slurry Seal	46,824	$2.70	**$126,500.00**
Fog Seal	46,824	$0.30	**$14,100**
Remove existing and replace 2.5" with TDOT Mix #2 (Local Streets) and recompact soil to existing grades (Additional Costs associated with this option as noted above)	46,824	$11.70	**$547,900**
Pulverize, blend existing and pave with 2.5" TDOT Mix #2 (Local Streets) (Additional Costs associated with this option as noted above)	46,824	$13.95	**$653,200**

As discussed in the geotechnical report in Appendix A, it is suggested that within a year of initial paving a fog seal be placed on the pavement as a rejuvenation to slow down the oxidation process that takes place in the pavement.

In conclusion, if options three or four are chosen; Psomas would be interested in assisting FCHOA in the preparation of the bidding package for the contractors, achieve clarity through answering the questions received by the contracting community, and reviewing the bids for the selection of a qualified contractor to perform the work.

APPENDIX A: Geotechnical Report from ConformaTECH

ConformaTECH

PAVEMENT SECTION EVALUATION
FOOTHILLS CLUSTERS HOMEOWNERS ASSOCIATION
EVANS MOUNTAIN DRIVE AT SKYLINE DRIVE
TUCSON, ARIZONA

Submitted To:

Psomas Inc.
333 East Wetmore Way Suite 450
Tucson, Arizona 85705

Submitted By:

ConformaTech, Inc.
1425 East Apache Park Place
Tucson, Arizona 85714

11 December 2015
CTEC Job No. 15-0527

ConformaTECH

11 December 2015
CTEC Job No. 15-0527

Psomas Inc.
333 East Wetmore Way Suite 450
Tucson, Arizona 85705

Attention: **Heidi Lasham, P.E.**
Project Manager

Re: **Pavement Section Evaluation**
Foothills Clusters Homeowners Association
Evans Mountain Drive at Skyline Drive
Tucson, Arizona

Our pavement section evaluation for the referenced project is herewith submitted. The report includes the results of site exploration, laboratory testing and engineering analyses. Recommendations for pavement section and subgrade preparation, based on the analyses, are presented.

This report was performed in general accordance with our proposal TG 15 08 07, dated 28 August 2015.

Should any questions arise concerning this report, we would be pleased to discuss them with you.

Respectfully submitted,
ConformaTech, Inc.

Registered Professional Engineer (Civil)
CERTIFICATE NO.
12561
CLYDE L.
PRETTI
DATE SIGNED 12/11/2015
ARIZONA U.S.A.
EXPIRES 12/31/2018

NOTICE
This is an electronic copy of a final document. The sealed original document is at ConformaTech, Inc. with Clyde L. Pretti Arizona Professional Engineer Number 12561.

Clyde L. Pretti, P.E.
Geotechnical Engineer

copies: Addressee (1-electronic)
File (1)

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ConformaTECH

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APPENDICES

ConformaTECH

1.0 INTRODUCTION

This report presents the results of a pavement section evaluation performed by ConformaTech, Inc. (CTEC) at the site of the Foothills Clusters residential development (the Foothills Clusters Homeowners Association FCHOA) located at Evans Mountain Drive and Skyline Drive, in Tucson, Arizona. The purpose of the CTEC services was to determine the thickness of the existing pavement and underlaying base materials and to provide new pavement section options.

This report was prepared for the exclusive use of our client for application only to the project discussed in the report. If changes in the nature, design or location of the site improvements as discussed in this report are planned or occur, the conclusions and recommendations of this report shall not continue to remain valid unless CTEC reviews the changes and provides a written verification or modification of the conclusions and recommendations of this report.

2.0 SITE DESCRIPTION

There are 35 separate street segments in the FCHOA that are private streets. The two remaining streets (Evans Mountain Drive and Ventana Canyon Drive) are public streets. Only the private streets are included in the pavement evaluation work of this report. Each street segment has from 4 to 23 residences.

The residences are single family and single story with concrete slab-on-grade floors. There is some vacant land in the common areas which has a moderate growth of desert vegetation. There are small washes in the area with some of the washes crossing the streets.

3.0 SITE EXPLORATION

Fourteen test holes were either drilled or hand dug. The original intent was to drill all of the test holes through the existing pavement surface with a drill rig using hollow stem flight augers. Due to the proximity of below ground utilities to the work area, six of the test locations were hand dug. At these locations, a section of the existing pavement was removed with a digging bar and the underlaying soils were hand excavated only deep enough to get a soil sample. These hand dug holes were no deeper that approximately 12 inches to avoid encountering a below ground utility. At the remaining test locations, borings were made through the pavement to depths of approximately 1 to 3 feet. Auger refusal on cobbles or boulders was encountered in 5 of the 8 test locations. The refusal depth varied from 1 to 2.5 feet below the surface of the pavement.

Bulk soil samples were taken of the pavement subsoils at each test location. The holes were backfilled with native soils and patched with hot mix asphalt.

4.0 EXISTING PAVEMENT AND BASE MATERIAL

The existing pavement materials were observed at the 14 test locations. The pavement thickness varied from approximately 1.5 to 4 inches. Most of the pavement was approximately 2 inches in thickness. It appears the site pavement is comprised of the original pavement with some areas of chip sealing.

The pavement on each street shows substantial cracking in the form of block and fatigue cracking. The block cracking is age and shrinkage related. The fatigue cracking is due to age and repeated traffic loadings.

No aggregate base materials below the pavement were observed during the work done at this site. Only native soils or fills comprised of native soils were observed during the site work.

The attached site plan in Appendix A shows the 14 test locations.

5.0 LABORATORY TESTING

A subgrade soil sample collected at each test location was tested for insitu moisture content, grain size analysis and for Atterberg limits. The laboratory test results are included in Appendix B.

6.0 PAVEMENT SUBGRADE SOILS

The subsoils encountered below the existing pavement structure were silty and clayey sands with varying amounts if gravel, cobble and some boulders. The soils were generally nonplastic or had a low plasticity. The soils exhibited a degree of lime cementation that was uncemented or weakly cemented. These soils are suitable for support of pavement.

7.0 PAVEMENT RECOMMENDATIONS

7.1 Pavement Options

The existing street pavement is approximately 35 years old. As pavement ages, it becomes more " brittle" and is subject to more and more cracking under the continued traffic loadings. The site pavement shows significant cracking that is age related.

Options for a new pavement surface include overlaying the existing pavement with new hot mix asphalt (AC) or the pavement could be overlayed with chip seal. The chip seal is comprised of paving oil and "chips" (small gravel). The existing cracking will "reflect" through the overlay AC and also through the chip seal beginning shortly after the overlay work is done giving a pavement surface with cracking similar to that now in place.

ConformaTECH

A reconstruction pavement option would be the complete removal of the existing asphalt paving and replacement with new hot mix asphalt over a layer of aggregate base following the Pima County pavement design guide as follows:

Design Life	20 years
Street	Local Street
Minimum SN	1.49 minimum SN (structural number) per Pima County
ADT	103 vehicles per day (two way) with all the vehicles in the design lane
Zr	-0.841 for a 80% level of reliability
So	0.35
Po	4.0
Pt	2.4
△PSI	1.6
Mr	26000 based on ADOT correlation of PI (plasticity index) and minus 200 sieve
SVF	1.7
Asphalt layer coefficient	0.44
Aggregate base coefficient	0.12
Drainage coefficient for AB	0.92

A 20 year design period was used with assumed traffic values as below. The following gives the determination of the design 18 kip single axle loads for the design period.

Vehicle	% of Traffic	18K EAL Factor	Vehicles per Day	Base Year Daily EAL (equivalent axle load)	20 Year EAL
Automobile	97	0.0008	100	0.080	584
Light Truck	1	0.01	1	0.010	73
Medium Truck	2	0.4	2	0.800	5840
				Total	6497

The design traffic loading (for each of the 35 street sections) was assumed to be a maximum 100 automobile trips per day, 1 light truck (Fed Ex delivery) per day, both garbage and recycle medium trucks at 4 trips each per week, 1 delivery medium truck per week and 2 emergency medium trucks per month. The daily traffic would be comprised of 103 vehicles with 97% cars, 1% light trucks and 2% medium trucks. This is a light traffic loading.

ConformaTECH

Using the pavement design method of the Pima County Department of Transportation roadway design manual with the above design information, a required structural number of 0.55 is determined. This structural number is low number because the traffic is light and the soils have a high relative bearing value. The minimum structural number required by the design method is 1.49 which requires 2.5 inches of asphalt over 4 inches of compacted aggregate base giving a structural number of 1.54 (2.5*0.44+4*0.12*0.92=1.54).

A "match the existing" option would be to remove the existing pavement and place a minimum 2 inches of new hot mix AC on the compacted subgrade soils. If desired, the existing pavement materials could be milled in place and mixed with the existing subgrade soils. The performance of this new pavement should be similar to that of the existing pavement.

7.2 Pavement Construction

The aggregate base course materials should comply with the latest requirements of the Standard Specifications for Public Improvements for Pima County/City of Tucson (SSPI of PC/COT). The asphaltic concrete should comply with the requirements of TDOT (Tucson Department of Transportaton) mix number 2 (local streets).

The asphaltic concrete and aggregate base course should be placed and compacted per the City of Tucson or Pima County recommendations.

7.3 Pavement Maintenance

A maintenance program should be implemented for the site pavement. Periodic sealing of the asphaltic concrete pavement structure will be required to extend the pavement life. The first pavement seal should be done approximately one year after initial construction. Successive sealing would be done on an "as needed" basis (usually 3 to 5 years). With time, the pavement will age and there will be cracking. Cracks should be sealed to prevent water infiltration. Eventually there would be a requirement for reconstruction of the original pavement.

Water should not be allowed to pond on or near the pavement surfaces. Intrusion of water into the subgrade soils below the pavement can cause pavement failure.

8.0 PAVEMENT MILLING and SUBGRADE EARTHWORK

8.1 Earthwork Construction

Areas of earthwork disturbance, trenching or excavation of fills that occur after completion of the earthwork should be backfilled and compacted in accordance with the recommendations of this report.

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8.2 Pulverizing the Existing Pavement

The existing pavement may be pulverized and mixed with the underlaying native soils. The mixture of pulverized pavement and existing soils should have a pavement subgrade bearing value that is equal to or better than that of just native soils. The pulverized pavement particles should be smaller than 1.5 inches in size.

8.3 Subgrade Materials Compaction

Upon completion of the existing pavement pulverization (see following if pavement is not pulverized) and mixing with the native subgrade soils, the subgrade materials should be moisture conditioned and compacted to a minimum depth of 8 inches. The materials should be compacted to a minimum 100% of the maximum dry density determined per ASTM D698 (Standard Proctor) at near optimum moisture.

If no pavement pulverizing is done, the subgrade soils below new pavement should be moisture conditioned and compacted as above.

8.4 Cobble, Boulder and Soft Soil Removal

Where cobbles or boulders are found at a grade above the bottom of the pavement base materials, the cobbles and boulders should be removed and the resulting excavation backfilled with structural fill. These backfill materials should be compacted to a minimum 100% if the maximum dry density determined per ASTM D698 (Standard Proctor) at near optimum moisture.

If soft soils are found in pavement subgrade areas during the project earthwork, the soft soils should be removed and replaced with structural fill (structure backfill). This backfill material should be compacted as above.

8.5 Structural Fill

Native soils may be used as structural fill below the new pavement provided the materials are cleaned of deleterious materials and screened to remove all materials greater than 3 inches in any dimension. Imported structural fills should comply with the requirements of structure backfill per the PC/COT SSPI Section 203 Earthwork part 203-5.02 Materials or as approved by the Geotechnical engineer.

All structural fills placed for pavement support should be moisture conditioned and compacted to a minimum depth of 8 inches. The structural fill soils should then be compacted to a minimum 100% of the maximum dry density determined per ASTM D698 (Standard Proctor) at near optimum moisture.

8.6 Excavation Conditions

All prospective contractors and/or subcontractors should visit the site and determine the proper equipment and excavation techniques.

8.7 Compliance

The recommendations of this report for pavement and other site improvements that are supported on prepared subgrade or compacted fills are dependent on compliance with the earthwork recommendations of this report. To assess compliance with the recommendations, a qualified geotechnical engineer should be retained to observe the preparation of subgrade soils and the placement and compaction of fills during project earthwork.

9.0 LIMITATIONS

The services performed for this project included analysis of the field and laboratory data and presentation of professional opinions and recommendations based, in part, on the data collected. The nature and extent of the actual site conditions may vary from those presented in this report. If such variations become evident during later phases of this project, we should be notified to review and possibly modify our conclusions and recommendations.

Our services were performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in this or similar localities. No warranty, express or implied, is made. We prepared the report as an aid in the design of the proposed project. This report is not a bidding document. Contractors reviewing this report must draw their own conclusions regarding site conditions and specific construction techniques to be used on this project.

This report is for the exclusive purpose of providing pavement section recommendations and/or testing information and recommendations. The scope of services for this project does not include, either specifically or by implication, any biological (e.g. mold, fungi, bacteria, endangered species) or environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.

Also, our services do not include evaluation of the consequences or effects of underlying geologic hazards or regional groundwater withdrawal.

Changes to site geotechnical conditions can be influenced by nearby construction. Also, the broadening of knowledge in engineering applications affects the information and recommendations of the profession. Accordingly, this document should not be used for design or construction after a period of three years beyond the report date.

APPENDIX A

⊕ Approximate Borehole Location

REFERENCE: Google Earth, 2014

NORTH

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1425 EAST APACHE PARK PLACE
TUCSON, ARIZONA 85714

JOB NO.: 15-0527

FIGURE 1
Site Plan
Foothills Clusters
Pavement Design
Tucson, Arizona

APPENDIX B

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Project	Foothills Clusters HOA Pavement Report
Location	Tucson, Arizona
Material	Soil
Sample Source	Test Location 1

Job No. 15-0527

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	99
3/4 in / 19 mm	99
1/2 in / 12.5 mm	98
3/8 in / 9.5 mm	96
1/4 in / 6.4 mm	92
#4, 4.75mm	89
#8, 2.36mm	83
#10, 2.00mm	81
#16, 1.18mm	74
#30, 0.60mm	66
#40, .425mm	60
#50, .300mm	56
#100, .150mm	43
#200, .075mm	29.2

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SM
Insitu Moisture Content	1.9 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 2		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	99
3/4 in / 19 mm	98
1/2 in / 12.5 mm	92
3/8 in / 9.5 mm	87
1/4 in / 6.4 mm	77
#4, 4.75mm	70
#8, 2.36mm	61
#10, 2.00mm	58
#16, 1.18mm	50
#30, 0.60mm	41
#40, .425mm	37
#50, .300mm	33
#100, .150mm	25
#200, .075mm	17.2

Liquid Limit (LL)	22
Plasticity Index (PI)	6
USCS Soil Classification	SC-SM
Insitu Moisture Content	4.4 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 3		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	94
3/4 in / 19 mm	85
1/2 in / 12.5 mm	78
3/8 in / 9.5 mm	73
1/4 in / 6.4 mm	67
#4, 4.75mm	63
#8, 2.36mm	54
#10, 2.00mm	53
#16, 1.18mm	46
#30, 0.60mm	39
#40, .425mm	35
#50, .300mm	31
#100, .150mm	24
#200, .075mm	17.4

Liquid Limit (LL)	19
Plasticity Index (PI)	2
USCS Soil Classification	SM
Insitu Moisture Content	3.2 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 4		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	93
3/4 in / 19 mm	89
1/2 in / 12.5 mm	82
3/8 in / 9.5 mm	77
1/4 in / 6.4 mm	70
#4, 4.75mm	65
#8, 2.36mm	57
#10, 2.00mm	53
#16, 1.18mm	46
#30, 0.60mm	38
#40, .425mm	33
#50, .300mm	29
#100, .150mm	22
#200, .075mm	15.3

Liquid Limit (LL)	20
Plasticity Index (PI)	2
USCS Soil Classification	SM
Insitu Moisture Content	2.1 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 5		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	97
3/4 in / 19 mm	91
1/2 in / 12.5 mm	83
3/8 in / 9.5 mm	77
1/4 in / 6.4 mm	68
#4, 4.75mm	61
#8, 2.36mm	53
#10, 2.00mm	50
#16, 1.18mm	44
#30, 0.60mm	36
#40, .425mm	32
#50, .300mm	28
#100, .150mm	21
#200, .075mm	14.7

Liquid Limit (LL)	19
Plasticity Index (PI)	2
USCS Soil Classification	SM
Insitu Moisture Content	2.5 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 6		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	100
3/4 in / 19 mm	99
1/2 in / 12.5 mm	97
3/8 in / 9.5 mm	94
1/4 in / 6.4 mm	89
#4, 4.75mm	83
#8, 2.36mm	69
#10, 2.00mm	65
#16, 1.18mm	52
#30, 0.60mm	39
#40, .425mm	34
#50, .300mm	29
#100, .150mm	22
#200, .075mm	14.8

Liquid Limit (LL)	23
Plasticity Index (PI)	7
USCS Soil Classification	SC-SM
Insitu Moisture Content	3.3 %

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Project	Foothills Clusters HOA Pavement Report
Location	Tucson, Arizona
Material	Soil
Sample Source	Test Location 7

Job No. 15-0527

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	100
3/4 in / 19 mm	99
1/2 in / 12.5 mm	98
3/8 in / 9.5 mm	97
1/4 in / 6.4 mm	94
#4, 4.75mm	90
#8, 2.36mm	81
#10, 2.00mm	78
#16, 1.18mm	66
#30, 0.60mm	54
#40, .425mm	48
#50, .300mm	42
#100, .150mm	33
#200, .075mm	25.2

Liquid Limit (LL)	20
Plasticity Index (PI)	5
USCS Soil Classification	SC-SM
Insitu Moisture Content	2.9 %

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Project	Foothills Clusters HOA Pavement Report
Location	Tucson, Arizona
Material	Soil
Sample Source	Test Location 8

Job No. 15-0527

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	97
3/4 in / 19 mm	91
1/2 in / 12.5 mm	82
3/8 in / 9.5 mm	76
1/4 in / 6.4 mm	67
#4, 4.75mm	62
#8, 2.36mm	55
#10, 2.00mm	53
#16, 1.18mm	46
#30, 0.60mm	37
#40, .425mm	33
#50, .300mm	29
#100, .150mm	22
#200, .075mm	15.8

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SM
Insitu Moisture Content	1.6 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 9		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	98
3/4 in / 19 mm	96
1/2 in / 12.5 mm	86
3/8 in / 9.5 mm	81
1/4 in / 6.4 mm	75
#4, 4.75mm	71
#8, 2.36mm	62
#10, 2.00mm	58
#16, 1.18mm	48
#30, 0.60mm	35
#40, .425mm	27
#50, .300mm	22
#100, .150mm	14
#200, .075mm	9.2

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SP-SM
Insitu Moisture Content	3.8 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 10		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	100
3/4 in / 19 mm	95
1/2 in / 12.5 mm	83
3/8 in / 9.5 mm	77
1/4 in / 6.4 mm	71
#4, 4.75mm	67
#8, 2.36mm	61
#10, 2.00mm	57
#16, 1.18mm	49
#30, 0.60mm	37
#40, .425mm	30
#50, .300mm	25
#100, .150mm	16
#200, .075mm	11.4

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SP-SM
Insitu Moisture Content	2.6 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 11		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	99
3/4 in / 19 mm	98
1/2 in / 12.5 mm	94
3/8 in / 9.5 mm	91
1/4 in / 6.4 mm	84
#4, 4.75mm	80
#8, 2.36mm	66
#10, 2.00mm	63
#16, 1.18mm	53
#30, 0.60mm	41
#40, .425mm	36
#50, .300mm	30
#100, .150mm	21
#200, .075mm	13.4

Liquid Limit (LL)	20
Plasticity Index (PI)	2
USCS Soil Classification	SM
Insitu Moisture Content	1.5 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 12		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	97
1 1/4 in / 32 mm	97
1 in / 25 mm	94
3/4 in / 19 mm	92
1/2 in / 12.5 mm	88
3/8 in / 9.5 mm	84
1/4 in / 6.4 mm	77
#4, 4.75mm	73
#8, 2.36mm	66
#10, 2.00mm	64
#16, 1.18mm	56
#30, 0.60mm	46
#40, .425mm	41
#50, .300mm	36
#100, .150mm	27
#200, .075mm	18.7

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SM
In Situ Moisture Content	2.3 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 13		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	95
3/4 in / 19 mm	92
1/2 in / 12.5 mm	88
3/8 in / 9.5 mm	84
1/4 in / 6.4 mm	76
#4, 4.75mm	71
#8, 2.36mm	62
#10, 2.00mm	58
#16, 1.18mm	47
#30, 0.60mm	36
#40, .425mm	31
#50, .300mm	27
#100, .150mm	20
#200, .075mm	14.3

Liquid Limit (LL)	25
Plasticity Index (PI)	7
USCS Soil Classification	SC-SM
Insitu Moisture Content	5.3 %

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Project	Foothills Clusters HOA Pavement Report	**Job No.**	15-0527
Location	Tucson, Arizona		
Material	Soil		
Sample Source	Test Location 14		

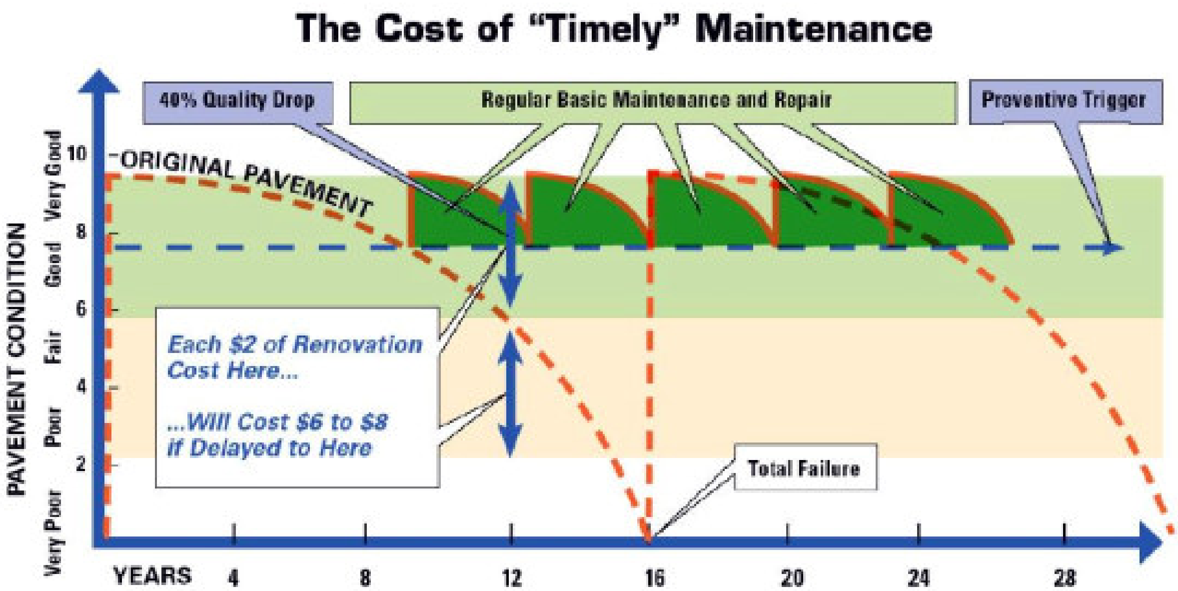
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES (ASTM C136/C117)

MECHANICAL ANALYSIS

SIEVE SIZE	% PASSING
6 in / 152mm	100
4 in / 100mm	100
3 in / 75mm	100
2 in / 50mm	100
1 1/2 in / 37.5mm	100
1 1/4 in / 32 mm	100
1 in / 25 mm	100
3/4 in / 19 mm	97
1/2 in / 12.5 mm	94
3/8 in / 9.5 mm	90
1/4 in / 6.4 mm	83
#4, 4.75mm	78
#8, 2.36mm	70
#10, 2.00mm	65
#16, 1.18mm	58
#30, 0.60mm	48
#40, .425mm	43
#50, .300mm	38
#100, .150mm	29
#200, .075mm	19.7

Liquid Limit (LL)	NV
Plasticity Index (PI)	NP
USCS Soil Classification	SM
Insitu Moisture Content	3.4 %

APPENDIX B: Pavement life cycle graph



The above graph shows (orange dashed line) the original pavement life. Then the orange solid with dark green shading underneath is the regular basic maintenance that is performed on the pavement to extend the life of the original pavement. Performing the regular maintenance will bring the pavement close to the original pavement quality and begin to wear again. The thought is that you do the regular maintenance needed and prolong the life of the pavement. However when the roads are neglected they will begin to fall into the poor and fair condition (orange shaded area) which will begin to cost additional money to repair and eventually if the roadway is neglected long enough it will require a full depth reconstruction.

APPENDIX C: Green Asphalt Pamphlet

APPENDIX D: Bumpy Road Ahead: America's Roughest Rides and Strategies to Make our Roads Smoother

Bumpy Roads Ahead:

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

October 3, 2013

a national transportation research group
Washington, DC
202-466-6706
tripnet.org

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.

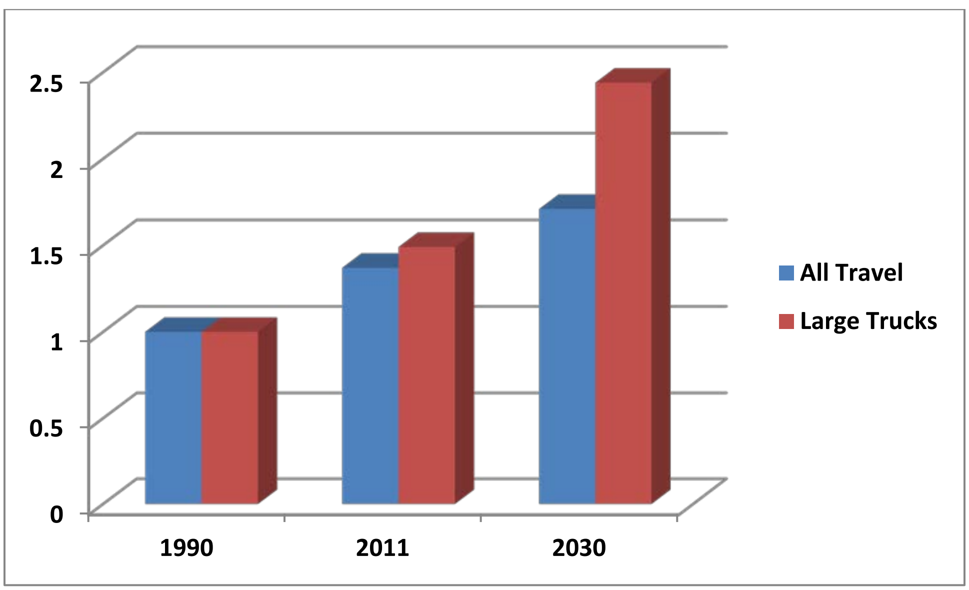
This report looks at the level of smoothness on the nation's major roads and the costs to motorists of driving on roads that have pavements in poor condition. Data on pavement conditions are from the Federal Highway Administration (FHWA), which annually gathers data on the condition of the nation's major 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
7	Tucson	$723
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
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

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

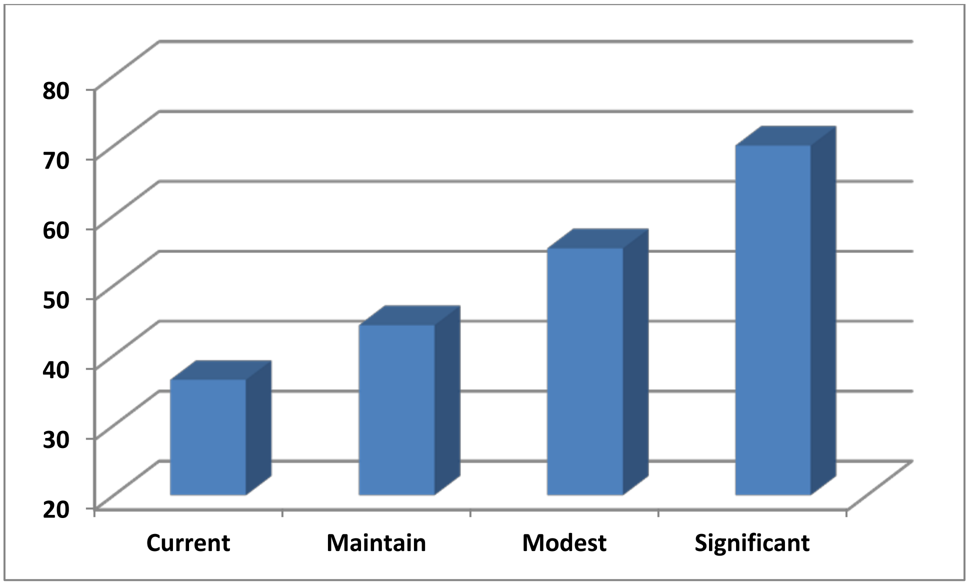
The U.S. Congress requires the U.S. Department of Transportation to provide a semi-annual comprehensive report on the condition, use and funding needs of the nation's surface transportation program. The most recent report, the *2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and 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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[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

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Appendix A: Pavement Conditions for Urban Areas with a Population of 500K or More

City	State	Poor	Mediocre	Fair	Good
Akron	OH	22%	27%	17%	34%
Albany	NY	27%	24%	23%	26%
Albuquerque	NM	18%	26%	12%	44%
Allentown--Bethlehem	PA	21%	32%	24%	23%
Atlanta	GA	1%	35%	5%	59%
Austin	TX	18%	17%	19%	47%
Bakersfield	CA	7%	37%	32%	23%
Baltimore	MD	30%	29%	14%	27%
Birmingham	AL	36%	25%	10%	28%
Boston	MA	39%	27%	12%	22%
Bridgeport--Stamford	CT	51%	29%	12%	8%
Buffalo	NY	14%	21%	21%	44%
Charlotte	NC	17%	27%	17%	40%
Chicago	IL	33%	39%	14%	14%
Cincinnati	OH	21%	25%	17%	37%
Cleveland	OH	26%	26%	12%	36%
Colorado Springs	CO	36%	36%	15%	13%
Columbus	OH	16%	30%	17%	36%
Concord	CA	42%	31%	5%	23%
Dallas--Fort Worth--Arlington	TX	36%	29%	18%	17%
Dayton	OH	15%	25%	16%	44%
Denver--Aurora	CO	37%	44%	9%	11%
Detroit	MI	35%	22%	12%	31%
El Paso	TX	21%	22%	22%	35%
Fresno	CA	25%	31%	11%	33%
Grand Rapids	MI	16%	24%	9%	51%
Hartford	CT	38%	32%	14%	16%
Honolulu	HI	43%	25%	14%	18%
Houston	TX	25%	31%	25%	19%
Indianapolis	IN	23%	42%	13%	22%
Indio--Cathedral City--Palm Springs	CA	28%	37%	5%	30%
Jacksonville	FL	8%	13%	16%	62%
Kansas City	MO	15%	29%	18%	38%
Lancaster--Palmdale	CA	17%	39%	23%	21%
Las Vegas	NV	11%	45%	15%	29%
Los Angeles--Long Beach--Santa Ana	CA	64%	26%	5%	5%
Louisville	KY	26%	30%	16%	27%
Memphis	TN	19%	28%	13%	40%

Rank	City	State	Poor
1	Los Angeles--Long Beach--Santa Ana	CA	64%
2	San Francisco--Oakland	CA	60%
3	San Jose	CA	56%
4	San Diego	CA	55%
5	Tucson	AZ	53%
6	New York--Newark	NY	51%
7	Bridgeport--Stamford	CT	51%
8	Milwaukee	WI	48%
9	New Orleans	LA	47%
10	Oklahoma City	OK	47%
11	Tulsa	OK	46%
12	Seattle	WA	45%
13	Honolulu	HI	43%
14	Sacramento	CA	43%
15	Concord	CA	42%
16	New Haven	CT	42%
17	Riverside--San Bernardino	CA	39%
18	Springfield	MA	39%
19	Boston	MA	39%
20	Hartford	CT	38%
21	Denver--Aurora	CO	37%
22	Philadelphia	PA	36%
23	Dallas--Fort Worth--Arlington	TX	36%
24	Colorado Springs	CO	36%
25	Birmingham	AL	36%
26	Providence	RI	36%
27	Omaha	NE	35%
28	Detroit	MI	35%
29	Chicago	IL	33%
30	Washington	DC	31%
31	Baltimore	MD	30%
32	Phoenix--Mesa	AZ	30%
33	Portland	OR	30%
34	Mission Viejo	CA	28%
35	Indio--Cathedral City--Palm Springs	CA	28%
36	Albany	NY	27%
37	Pittsburgh	PA	27%
38	Louisville	KY	26%

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Appendix A: Pavement Conditions for Urban Areas with a Population of 500K or More

City	State	Poor	Mediocre	Fair	Good
Miami	FL	20%	22%	17%	42%
Milwaukee	WI	48%	30%	15%	7%
Minneapolis--St. Paul	MN	18%	32%	20%	31%
Mission Viejo	CA	28%	44%	11%	17%
Nashville-Davidson	TN	10%	21%	10%	59%
New Haven	CT	42%	30%	10%	18%
New Orleans	LA	47%	25%	12%	16%
New York--Newark	NY	51%	23%	11%	14%
Oklahoma City	OK	47%	27%	14%	13%
Omaha	NE	35%	32%	6%	27%
Orlando	FL	13%	12%	15%	60%
Philadelphia	PA	36%	37%	13%	14%
Phoenix--Mesa	AZ	30%	17%	14%	39%
Pittsburgh	PA	27%	21%	20%	32%
Portland	OR	30%	32%	17%	21%
Poughkeepsie--Newburgh	NY	10%	44%	25%	21%
Providence	RI	36%	29%	13%	22%
Raleigh	NC	14%	11%	19%	56%
Richmond	VA	10%	39%	20%	31%
Riverside--San Bernardino	CA	39%	40%	8%	13%
Rochester	NY	17%	17%	23%	43%
Sacramento	CA	43%	37%	5%	15%
Salt Lake City	UT	8%	31%	21%	40%
San Antonio	TX	18%	24%	24%	35%
San Diego	CA	55%	31%	5%	9%
San Francisco--Oakland	CA	60%	26%	5%	9%
San Jose	CA	56%	21%	8%	15%
Sarasota--Bradenton	FL	7%	11%	14%	68%
Seattle	WA	45%	30%	9%	16%
Springfield	MA	39%	21%	13%	27%
St. Louis	MO	16%	24%	17%	42%
Tampa--St. Petersburg	FL	14%	17%	18%	51%
Toledo	OH	21%	24%	16%	39%
Tucson	AZ	53%	27%	9%	11%
Tulsa	OK	46%	30%	10%	14%
Virginia Beach	VA	15%	36%	15%	34%
Washington	DC	31%	29%	17%	23%

Rank	City	State	Poor
39	Cleveland	OH	26%
40	Fresno	CA	25%
41	Houston	TX	25%
42	Indianapolis	IN	23%
43	Akron	OH	22%
44	Toledo	OH	21%
45	Cincinnati	OH	21%
46	El Paso	TX	21%
47	Allentown--Bethlehem	PA	21%
48	Miami	FL	20%
49	Memphis	TN	19%
50	Minneapolis--St. Paul	MN	18%
51	Albuquerque	NM	18%
52	Austin	TX	18%
53	San Antonio	TX	18%
54	Rochester	NY	17%
55	Lancaster--Palmdale	CA	17%
56	Charlotte	NC	17%
57	Grand Rapids	MI	16%
58	Columbus	OH	16%
59	St. Louis	MO	16%
60	Dayton	OH	15%
61	Virginia Beach	VA	15%
62	Kansas City	MO	15%
63	Tampa--St. Petersburg	FL	14%
64	Raleigh	NC	14%
65	Buffalo	NY	14%
66	Orlando	FL	13%
67	Las Vegas	NV	11%
68	Richmond	VA	10%
69	Nashville-Davidson	TN	10%
70	Poughkeepsie--Newburgh	NY	10%
71	Jacksonville	FL	8%
72	Salt Lake City	UT	8%
73	Sarasota--Bradenton	FL	7%
74	Bakersfield	CA	7%
75	Atlanta	GA	1%

Source: TRIP

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Appendix B: Pavement Conditons for Urban Areas with a Population between 250K and 500K

City	State	Poor	Mediocre	Fair	Good
Anchorage	AL	29%	33%	24%	14%
Ann Arbor	MI	16%	30%	8%	45%
Antioch	CA	64%	14%	4%	18%
Asheville	NC	10%	18%	17%	56%
Augusta-Richmond County	GA	6%	27%	12%	55%
Barnstable Town	MA	15%	35%	20%	30%
Baton Rouge	LA	32%	35%	21%	12%
Boise City	ID	25%	10%	11%	53%
Canton	OH	15%	32%	15%	38%
Cape Coral	FL	5%	11%	12%	71%
Charleston--North Charleston	SC	8%	31%	25%	36%
Chattanooga	TN	10%	30%	6%	54%
Columbia, SC	SC	9%	19%	23%	50%
Corpus Christi	TX	40%	18%	19%	24%
Davenport	IA	34%	25%	16%	26%
Daytona Beach--Port Orange	FL	10%	11%	11%	68%
Denton--Lewisville	TX	11%	34%	33%	22%
Des Moines	IA	38%	22%	20%	20%
Durham	NC	6%	22%	18%	53%
Eugene	OR	9%	36%	21%	34%
Fayetteville	NC	10%	21%	26%	43%
Flint	MI	26%	20%	11%	43%
Fort Wayne	IN	32%	36%	14%	18%
Greensboro	NC	10%	19%	16%	55%
Greenville	SC	16%	35%	25%	24%
Harrisburg	PA	12%	21%	36%	31%
Hemet	CA	48%	45%	8%	0%
Hickory	NC	9%	16%	22%	53%
Jackson, MS	MS	45%	23%	12%	21%
Kissimmee	FL	8%	11%	11%	70%
Knoxville	TN	8%	22%	11%	59%

Rank	City	State	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	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	AL	29%
21	Oxnard	CA	29%
22	Shreveport	LA	28%
23	Flint	MI	26%
24	Syracuse	NY	26%
25	Boise City	ID	25%
26	Victorville--Hesperia--Apple Valley	CA	25%
27	Lancaster	PA	24%
28	Reading	PA	21%
29	Youngstown	OH	20%
30	Lorain--Elyria	OH	19%
31	Wichita	KS	19%

Appendix B: Pavement Conditons for Urban Areas with a Population between 250K and 500K

City	State	Poor	Mediocre	Fair	Good
Lancaster	PA	24%	19%	21%	36%
Lansing	MI	10%	39%	6%	46%
Lexington-Fayette	KY	8%	15%	14%	63%
Little Rock	AK	13%	43%	12%	32%
Lorain--Elyria	OH	19%	27%	17%	36%
Madison	WI	37%	36%	21%	7%
McAllen	TX	6%	16%	24%	54%
Mobile	AL	15%	13%	14%	58%
Modesto	CA	31%	39%	16%	14%
Ogden--Layton	UT	4%	29%	17%	50%
Oxnard	CA	29%	39%	16%	17%
Palm Bay--Melbourne	FL	14%	5%	19%	63%
Pensacola	FL	7%	9%	16%	68%
Port St. Lucie	FL	11%	23%	17%	49%
Provo--Orem	UT	3%	38%	12%	47%
Reading	PA	21%	30%	34%	15%
Reno	NV	55%	31%	2%	12%
Santa Rosa	CA	51%	27%	8%	15%
Scranton	PA	32%	34%	14%	20%
Shreveport	LA	28%	39%	17%	16%
South Bend	IN	34%	26%	15%	26%
Spokane	WA	45%	23%	19%	13%
Stockton	CA	40%	23%	8%	29%
Syracuse	NY	26%	16%	16%	43%
Temecula--Murrieta	CA	43%	38%	9%	11%
Trenton	NJ	48%	17%	10%	24%
Victorville--Hesperia--Apple Valley	CA	25%	42%	19%	14%
Wichita	KS	19%	48%	13%	20%
Winston-Salem	NC	9%	23%	25%	43%
Worcester	MA	41%	32%	10%	17%
Youngstown	OH	20%	25%	16%	39%

Rank	City	State	Poor
32	Ann Arbor	MI	16%
33	Greenville	SC	16%
34	Canton	OH	15%
35	Mobile	AL	15%
36	Barnstable Town	MA	15%
37	Palm Bay--Melbourne	FL	14%
38	Little Rock	AK	13%
39	Harrisburg	PA	12%
40	Port St. Lucie	FL	11%
41	Denton--Lewisville	TX	11%
42	Chattanooga	TN	10%
43	Fayetteville	NC	10%
44	Lansing	MI	10%
45	Daytona Beach--Port Orange	FL	10%
46	Greensboro	NC	10%
47	Asheville	NC	10%
48	Eugene	OR	9%
49	Winston-Salem	NC	9%
50	Hickory	NC	9%
51	Columbia, SC	SC	9%
52	Charleston--North Charleston	SC	8%
53	Knoxville	TN	8%
54	Lexington-Fayette	KY	8%
55	Kissimmee	FL	8%
56	Pensacola	FL	7%
57	Durham	NC	6%
58	McAllen	TX	6%
59	Augusta-Richmond County	GA	6%
60	Cape Coral	FL	5%
61	Ogden--Layton	UT	4%
62	Provo--Orem	UT	3%

Appendix C: Additional VOC for Urban Areas with Populations over 500K

City	State	VOC
Akron	OH	$423
Albany	NY	$479
Albuquerque	NM	$401
Allentown--Bethlehem	PA	$450
Atlanta	GA	$201
Austin	TX	$351
Bakersfield	CA	$323
Baltimore	MD	$523
Birmingham	AL	$601
Boston	MA	$570
Bridgeport--Stamford	CT	$669
Buffalo	NY	$316
Charlotte	NC	$378
Chicago	IL	$567
Cincinnati	OH	$409
Cleveland	OH	$458
Colorado Springs	CO	$589
Columbus	OH	$375
Concord	CA	$623
Dallas--Fort Worth--Arlington	TX	$615
Dayton	OH	$336
Denver--Aurora	CO	$615
Detroit	MI	$536
El Paso	TX	$424
Fresno	CA	$456
Grand Rapids	MI	$327
Hartford	CT	$563
Honolulu	HI	$598
Houston	TX	$506
Indianapolis	IN	$461
Indio--Cathedral City--Palm Springs	CA	$501
Jacksonville	FL	$206
Kansas City	MO	$370
Lancaster--Palmdale	CA	$421
Las Vegas	NV	$365
Los Angeles--Long Beach--Santa Ana	CA	$832
Louisville	KY	$512
Memphis	TN	$399
Miami	FL	$380
Milwaukee	WI	$700
Minneapolis--St. Paul	MN	$436
Mission Viejo	CA	$542
Nashville-Davidson	TN	$254
New Haven	CT	$582
New Orleans	LA	$687

Rank	City	State	VOC
1	Los Angeles--Long Beach--Santa Ana	CA	$832
2	Tulsa	OK	$784
3	San Francisco--Oakland	CA	$782
4	Oklahoma City	OK	$782
5	San Diego	CA	$758
6	San Jose	CA	$737
7	Tucson	AZ	$723
8	Milwaukee	WI	$700
9	New Orleans	LA	$687
10	New York--Newark	NY	$673
11	Bridgeport--Stamford	CT	$669
12	Sacramento	CA	$658
13	Riverside--San Bernardino	CA	$638
14	Seattle	WA	$625
15	Concord	CA	$623
16	Denver--Aurora	CO	$615
17	Dallas--Fort Worth--Arlington	TX	$615
18	Birmingham	AL	$601
19	Honolulu	HI	$598
20	Colorado Springs	CO	$589
21	New Haven	CT	$582
22	Philadelphia	PA	$572
23	Omaha	NE	$571
24	Boston	MA	$570
25	Chicago	IL	$567
26	Hartford	CT	$563
27	Springfield	MA	$553
28	Mission Viejo	CA	$542
29	Detroit	MI	$536
30	Providence	RI	$528
31	Baltimore	MD	$523
32	Washington	DC	$517
33	Louisville	KY	$512
34	Houston	TX	$506
35	Indio--Cathedral City--Palm Springs	CA	$501
36	Albany	NY	$479
37	Indianapolis	IN	$461
38	Phoenix--Mesa	AZ	$459
39	Cleveland	OH	$458
40	Fresno	CA	$456
41	Allentown--Bethlehem	PA	$450
42	Portland	OR	$440
43	Minneapolis--St. Paul	MN	$436
44	Pittsburgh	PA	$432
45	El Paso	TX	$424

Appendix C: Additional VOC for Urban Areas with Populations over 500K

City	State	VOC
New York--Newark	NY	$673
Oklahoma City	OK	$782
Omaha	NE	$571
Orlando	FL	$254
Philadelphia	PA	$572
Phoenix--Mesa	AZ	$459
Pittsburgh	PA	$432
Portland	OR	$440
Poughkeepsie--Newburgh	NY	$345
Providence	RI	$528
Raleigh	NC	$283
Richmond	VA	$353
Riverside--San Bernardino	CA	$638
Rochester	NY	$319
Sacramento	CA	$658
Salt Lake City	UT	$290
San Antonio	TX	$391
San Diego	CA	$758
San Francisco--Oakland	CA	$782
San Jose	CA	$737
Sarasota--Bradenton	FL	$178
Seattle	WA	$625
Springfield	MA	$553
St. Louis	MO	$365
Tampa--St. Petersburg	FL	$299
Toledo	OH	$404
Tucson	AZ	$723
Tulsa	OK	$784
Virginia Beach	VA	$385
Washington	DC	$517

Rank	City	State	VOC
46	Akron	OH	$423
47	Lancaster--Palmdale	CA	$421
48	Cincinnati	OH	$409
49	Toledo	OH	$404
50	Albuquerque	NM	$401
51	Memphis	TN	$399
52	San Antonio	TX	$391
53	Virginia Beach	VA	$385
54	Miami	FL	$380
55	Charlotte	NC	$378
56	Columbus	OH	$375
57	Kansas City	MO	$370
58	Las Vegas	NV	$365
59	St. Louis	MO	$365
60	Richmond	VA	$353
61	Austin	TX	$351
62	Poughkeepsie--Newburgh	NY	$345
63	Dayton	OH	$336
64	Grand Rapids	MI	$327
65	Bakersfield	CA	$323
66	Rochester	NY	$319
67	Buffalo	NY	$316
68	Tampa--St. Petersburg	FL	$299
69	Salt Lake City	UT	$290
70	Raleigh	NC	$283
71	Nashville-Davidson	TN	$254
72	Orlando	FL	$254
73	Jacksonville	FL	$206
74	Atlanta	GA	$201
75	Sarasota--Bradenton	FL	$178

Source: TRIP

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APPENDIX D: Additional VOC for Urban Areas with Populations between 250K and 500K

City	State	VOC
Anchorage	AL	$475
Ann Arbor	MI	$351
Antioch	CA	$793
Asheville	NC	$251
Augusta-Richmond County	GA	$240
Barnstable Town	MA	$362
Baton Rouge	LA	$581
Boise City	ID	$394
Canton	OH	$366
Cape Coral	FL	$151
Charleston--North Charleston	SC	$299
Chattanooga	TN	$284
Columbia, SC	SC	$248
Corpus Christi	TX	$614
Davenport	IA	$548
Daytona Beach--Port Orange	FL	$200
Denton--Lewisville	TX	$373
Des Moines	IA	$591
Durham	NC	$235
Eugene	OR	$308
Fayetteville	NC	$289
Flint	MI	$425
Fort Wayne	IN	$530
Greensboro	NC	$255
Greenville	SC	$407
Harrisburg	PA	$305
Hemet	CA	$738
Hickory	NC	$247
Jackson, MS	MS	$741
Kissimmee	FL	$176
Knoxville	TN	$237
Lancaster	PA	$398
Lansing	MI	$305
Lexington-Fayette	KY	$214
Little Rock	AK	$404
Lorain--Elyria	OH	$398
Madison	WI	$615
McAllen	TX	$213
Mobile	AL	$303
Modesto	CA	$560
Ogden--Layton	UT	$225
Oxnard	CA	$534
Palm Bay--Melbourne	FL	$238
Pensacola	FL	$166

Rank	City	State	VOC
1	Antioch	CA	$793
2	Reno	NV	$771
3	Jackson, MS	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
21	South Bend	IN	$515
22	Victorville--Hesperia--Apple Valley	CA	$515
23	Anchorage	AL	$475
24	Wichita	KS	$467
25	Reading	PA	$444
26	Flint	MI	$425
27	Greenville	SC	$407
28	Little Rock	AK	$404
29	Lorain--Elyria	OH	$398
30	Lancaster	PA	$398
31	Boise City	ID	$394
32	Youngstown	OH	$393
33	Syracuse	NY	$393
34	Denton--Lewisville	TX	$373
35	Canton	OH	$366
36	Barnstable Town	MA	$362
37	Ann Arbor	MI	$351
38	Eugene	OR	$308
39	Lansing	MI	$305
40	Harrisburg	PA	$305
41	Mobile	AL	$303
42	Charleston--North Charleston	SC	$299
43	Fayetteville	NC	$289
44	Winston-Salem	NC	$285

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APPENDIX D: Additional VOC for Urban Areas with Populations between 250K and 500K

City	State	VOC
Port St. Lucie	FL	$281
Provo--Orem	UT	$241
Reading	PA	$444
Reno	NV	$771
Santa Rosa	CA	$709
Scranton	PA	$539
Shreveport	LA	$549
South Bend	IN	$515
Spokane	WA	$619
Stockton	CA	$584
Syracuse	NY	$393
Temecula--Murrieta	CA	$664
Trenton	NJ	$636
Victorville--Hesperia--Apple Valley	CA	$515
Wichita	KS	$467
Winston-Salem	NC	$285
Worcester	MA	$600
Youngstown	OH	$393

Rank	City	State	VOC
45	Chattanooga	TN	$284
46	Port St. Lucie	FL	$281
47	Greensboro	NC	$255
48	Asheville	NC	$251
49	Columbia, SC	SC	$248
50	Hickory	NC	$247
51	Provo--Orem	UT	$241
52	Augusta-Richmond County	GA	$240
53	Palm Bay--Melbourne	FL	$238
54	Knoxville	TN	$237
55	Durham	NC	$235
56	Ogden--Layton	UT	$225
57	Lexington-Fayette	KY	$214
58	McAllen	TX	$213
59	Daytona Beach--Port Orange	FL	$200
60	Kissimmee	FL	$176
61	Pensacola	FL	$166
62	Cape Coral	FL	$151

Source: TRIP