Freeway Pavement Noise Reduction Analysis

Summary Report

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Prepared for:

MARICOPA ASSOCIATION of GOVERNMENTS

Prepared by:

Kimley»Horn

TABLE OF CONTENTS

List of Figures

List of Tables

1 EXECUTIVE SUMMARY

1.1 Purpose

The Maricopa Association of Governments (MAG) and the Arizona Department of Transportation (ADOT) have partnered on this Freeway Pavement Noise Reduction Analysis to better understand the noise reduction pavement surface treatments available and their benefits and limitations for the urban freeway system within Maricopa County. Most of the region's freeways were covered with a rubberized asphalt overlay 10 or more years ago in an effort to reduce noise generated by vehicle tires. As the service life of the rubberized asphalt overlay comes to an end, a decision needs to be made whether to replace the rubberized asphalt overlay with a new rubberized asphalt overlay or utilize an alternative surface treatment.

1.2 Rubberized Asphalt Overlay Existing Conditions and Replacement Priorities

Figure ES-1 shows the condition of the rubberized asphalt overlay based on 2018 pavement condition data provided by ADOT. The following segments, totaling approximately 13.3 centerline miles, have greater than 50% of the rubberized asphalt pavement considered to be in 'failing' condition:

- I-17 between Dunlap Avenue and State Route (SR)-101L (Agua Fria);
- SR-101L (Price) between SR-202L (Red Mountain) and US-60; and
- SR-202L (Santan) between Kyrene Road and McClintock Drive.

The following segments, totaling approximately 43.9 centerline miles, have between 25% and 50% of the rubberized asphalt pavement considered to be in 'failing' condition:

- I-10 between 43rd Avenue and I-17;
- I-17 between I-10 (Split Interchange) and 19th Avenue;
- SR-51 between I-10 and Shea Boulevard;
- SR-101L (Agua Fria) between Union Hills Drive and I-17;
- SR-143 between Van Buren Street and Belleview Street;
- SR-202L (Santan) between 48th Street and Kyrene Road; and
- US-60 between I-10 and Crismon Road.

Approximately 129.3 centerline miles of rubberized asphalt overlay have been in place longer than the expected 10-year service life. Recommendations for the prioritization of rubberized asphalt overlay replacement have been broken down into three prioritization levels:

- **High-Priority Replacement Need:** Pavement failure percentage of greater than 25%;
- **Moderate-Priority Replacement Need:** Pavement failure percentage between 10% and 25% **or** the rubberized asphalt is beyond its 10-year service life; and
- **Low-Priority Replacement Need:** Pavement failure of less than 10% **and** the rubberized asphalt surface is within the 10-year service life.

The rubberized asphalt overlay replacement priorities are presented in **Figure ES-2**.

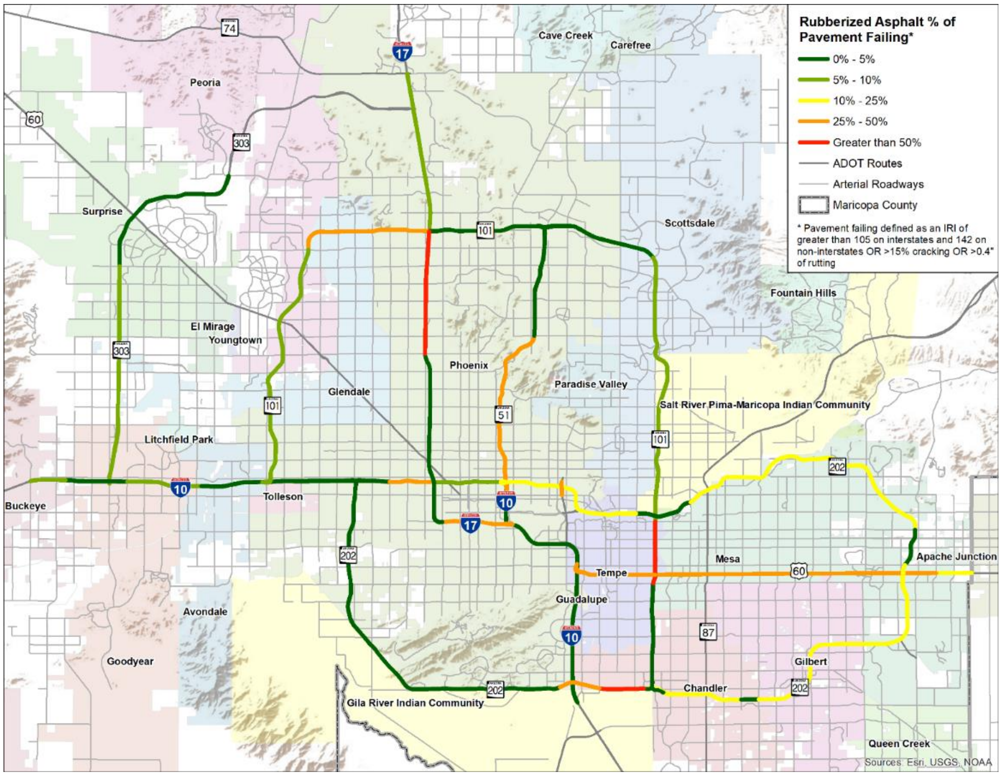


Figure ES-1 – Percentage of 'Failing' Rubberized Asphalt Pavement in 2018 by Freeway Segment

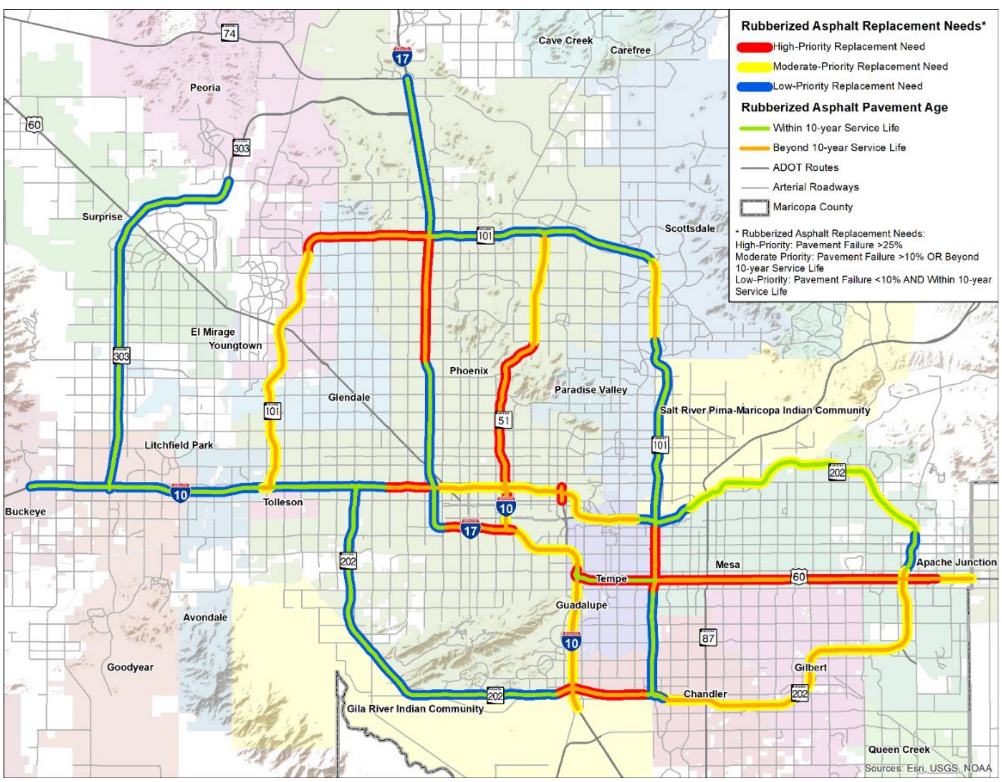


Figure ES-2 – Rubberized Asphalt Replacement Needs

As shown in **Figure ES-2**, the locations of high-priority rubberized asphalt replacement needs are:

- I-10 between 43rd Avenue and I-17 (programmed to be resurfaced in fiscal year (FY) 2021);
- I-17 between I-10 (Split Interchange) and 19th Avenue (programmed to be widened for auxiliary lanes in FY 2027);
- I-17 between Dunlap Avenue and SR-101L (Agua Fria);
- SR-51 between I-10 and Shea Boulevard;
- SR-101L (Agua Fria) between Union Hills Drive and I-17 (programmed to be widened with general purpose lanes in FY 2026);
- SR-101L between SR-202L (Red Mountain) and Baseline Road;
- SR-143 between Van Buren Street and Belleview Street;
- SR-202L (Santan) between McClintock Drive and 48th Street (programmed to be widened with general purpose lanes in FY 2030); and
- US-60 between I-10 and Crismon Road.

Several of these segments have a subbase constructed several decades ago, where the subbase and concrete will need to be evaluated to determine if they need to be replaced or rehabilitated to avoid negatively impacting the service life of the pavement noise reduction treatment. Segments of most concern are:

- I-17 between Dunlap Avenue and SR-101L (Agua Fria) – much of the subbase along this section was constructed in the 1960s;
- US-60 between I-10 and SR-101L (Price) – the subbase along this segment was constructed in the 1960s and 1970s; and
- US-60 between SR-101L (Price) and SR-87 – the subbase along this segment was constructed in the 1970s.

1.3 Freeway Pavement Noise Reduction Treatment Alternatives

There are two primary pavement surface treatment types used on freeways – concrete and asphalt. **Table ES-1** summarizes the advantages and disadvantages of concrete and asphalt pavement surface treatments.

For asphalt, the primary freeway noise reduction treatment is rubberized asphalt – what the region currently uses. For concrete, three potentially viable alternatives for pavement treatments are: diamond grind, whisper grind, and Skidabrader. All four of these freeway pavement noise reduction treatment alternatives provide similar levels of improved surface friction compared to untreated asphalt or concrete.

Figure ES-3 summarizes the typical pavement surface noise levels at first application and at end of service life for untreated asphalt, untreated concrete, and for the four analyzed alternatives. The rubberized asphalt, diamond grind, and whisper grind treatments all show reductions in noise levels compared to untreated concrete, with the effectiveness of that noise reduction decreasing over time, particularly for the rubberized asphalt. Skidabrader does not reduce noise levels, and based on test section results of these treatments implemented in 2019, it should be noted that ADOT does not consider Skidabrader a viable pavement noise reduction treatment alternative.

Table ES-1 – Concrete and Asphalt Surface Comparison

Surface Attribute	Concrete Surface	Asphalt Surface
Noise Level	**Advantage**: Little change over time **Disadvantage**: Typically higher than asphalt initially	**Advantage**: Typically lower initially than concrete **Disadvantage**: Increases over time, ultimately being equal to or higher than concrete
Life-Cycle Cost	**Advantage**: Lower than asphalt over service life **Disadvantage**: Typically higher than asphalt initially	**Advantage**: Typically lower than concrete initially **Disadvantage**: Higher than concrete over service life
Road Smoothness	**Advantage:** Little change over time **Disadvantage**: Has expansion cracks from heat/cold cycles	**Advantage**: Has no expansion cracks **Disadvantage**: Raveling and cracking increase over time, especially when traffic volumes are high or there are many heavy vehicles (trucks)
Aesthetics	**Advantage**: Little change over time **Disadvantage**: Hard to see white pavement markings unless provide black outline of markings on white concrete surface	**Advantage**: Easy to see white pavement markings on dark asphalt surface **Disadvantage**: Deteriorates over time
Environmental Impacts	**Advantage**: Cooler than asphalt during the day **Disadvantage**: Hotter than asphalt at night; cannot easily be recycled	**Advantage**: Cooler than concrete at night; can easily be recycled; provides slight reduction in PM-10 emissions compared to untreated concrete[1]. **Disadvantage**: Hotter than concrete during the day

1. The MAG 2012 Five Percent Plan for PM-10 for the Maricopa County Nonattainment Area indicates that, based on data provided by ADOT and Arizona State University, rubberized asphalt provides a PM-10 emission reduction of 0.034 tons/lane-mile/year (assuming 17,000 vehicles/lane/day). This represents a 30%-50% reduction in tire wear emissions with rubberized asphalt compared to untreated concrete; tire wear emissions represent less than 1% of overall emissions.

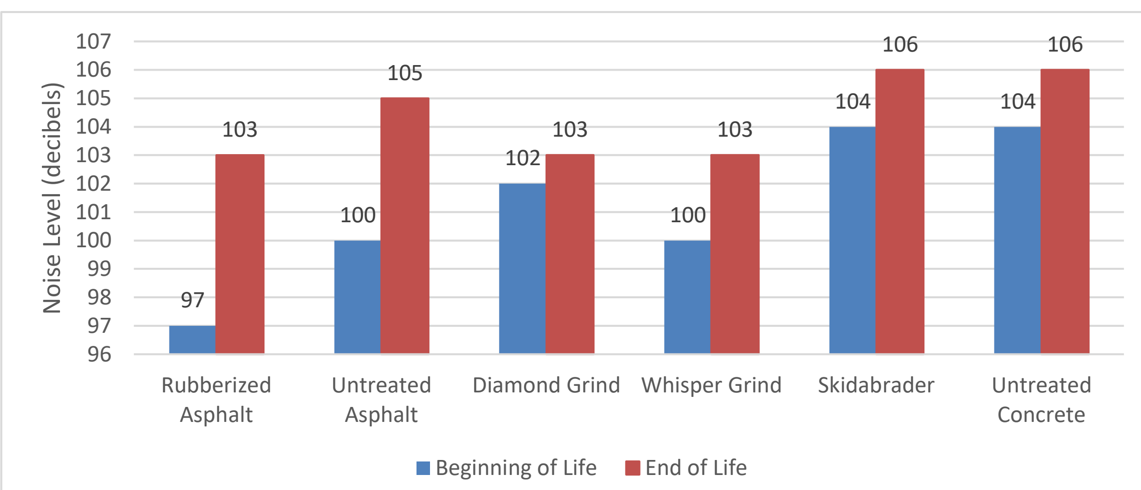


Figure ES-3 – Typical Pavement Surface Noise Level over Service Life

The rubberized asphalt produces the lowest noise level at installation (97 decibels (dBA)) of the four treatment alternatives but increases in noise level by approximately 0.5 dBA per year to the point where it has a similar noise level at the end of service life (103 dBA) as the diamond grind and whisper grind concrete treatments. It is important to note the rubberized asphalt has a 10-year service life while the concrete treatments have a 15-year service life.

The diamond grind produces the highest noise level at installation (102 dBA) of the treatment alternatives that reduce noise but remains relatively constant over time such that the noise level at the end of service life (103 dBA) is similar to the rubberized asphalt and whisper grind treatments.

The whisper grind produces the lowest noise level at installation (100 dBA) of the three concrete treatment alternatives but increases in noise level by approximately 0.25 dBA per year to the point where it has a similar noise level at the end of service life (103 dBA) as the rubberized asphalt and diamond grind treatments.

With 3 dBA being the minimum noise difference most humans can hear, rubberized asphalt provides a significant improvement in noise reduction over diamond grind, whisper grind, and Skidabrader for approximately the first half of their respective service lives (i.e., the first 5-7 years). For the second half of their service lives, there is no significant difference in noise reduction between that provided by rubberized asphalt, diamond grind, and whisper grind, but all three do have a significant improvement in noise reduction of at least 3 dBA compared to untreated concrete.

Table ES-2 summarizes the noise levels, life span, and planning-level cost estimates for the pavement noise reduction treatment alternatives.

Table ES-2 – Noise Levels, Life Span, and Costs for Pavement Noise Reduction Treatment Alternatives

Pavement Noise Reduction Treatment	Typical Noise at Beginning of Service Life (dBA)	Typical Noise at End of Service Life (dBA)	Life Span (years)	Costs[1]			
				Per Lane Mile	Corridor[2]	Life-Cycle Corridor[3]	Life-Cycle System[4]
Rubberized Asphalt	97	103	10	$116,000	$9,280,000	$41,760,000	$1,239,901,000
Diamond Grind	102	103	15	$123,000	$9,840,000	$29,520,000	$912,784,000
Whisper Grind	100	103	15	$150,000	$12,000,000	$36,000,000	$1,098,290,000
Skidabrader	104	106	15	$90,000	$7,200,000	$21,600,000	$686,054,000

1. Bridge joint replacement work is included in the diamond grind, whisper grind, and Skidabrader cost estimates.
2. Corridor costs based on a new 10-mile, eight-lane section (four lanes in each direction) with auxiliary lanes and shoulders.
3. Life-cycle costs based on corridor costs over a period of 25 years.
4. System costs based on maintenance and construction cost of the treatment for the entirety of the freeway system that currently has rubberized asphalt over a period of 25 years.

1.4 Recommended Pavement Noise Reduction Treatment

Each of the four pavement noise reduction treatment alternatives has advantages and disadvantages. The scenarios where each treatment alternative would likely be the preferred treatment are described below:

- **Rubberized asphalt**: appropriate treatment where noise reduction is a much higher priority than cost-effectiveness and where replacement of the rubberized asphalt will occur every 6 years to maintain a significant level of noise reduction; rubberized asphalt is the least cost-effective treatment alternative from a life-cycle cost perspective of the three alternatives that reduce noise;
- **Diamond grind**: appropriate treatment where noise reduction and cost-effectiveness are both priorities and where replacement of the diamond grind treatment will occur every 15 years to maintain a significant level of noise reduction; diamond grind is the most cost-effective treatment alternative from a life-cycle cost perspective at reducing noise;
- **Whisper grind**: appropriate treatment where noise reduction is a slightly higher priority than cost-effectiveness and where replacement of the whisper grind treatment will occur every 15 years to maintain a significant level of noise reduction; whisper grind is more cost-effective than rubberized asphalt but less cost-effective than diamond grind from a life-cycle cost perspective at reducing noise;
- **Skidabrader**: appropriate treatment where improving roadway surface friction and cost-effectiveness are both priorities and where replacement of the Skidabrader treatment will occur every 15 years to maintain a desirable level of surface friction; this treatment should not be considered if noise reduction is desired; further, ADOT does not consider Skidabrader a viable noise reduction treatment option.

Considering the challenges the MAG region and state have had in recent years – and are projected to continue to have in the future – to secure adequate funding for roadway maintenance, consideration should be given to replacement of the rubberized asphalt overlay with a diamond grind treatment.

To date, there has only been limited research on how different pavement surface treatments affect tire wear and PM-10 emissions. Arizona State University conducted research in 2006 for ADOT in the Deck Park tunnel on I-10 that indicated newly installed rubberized asphalt reduced tire wear and PM-10 emissions compared to untreated concrete. No research documentation was available, however, related to how the different concrete noise reduction treatments (i.e., diamond grind, whisper grind, and Skidabrader) affect tire wear and PM-10 emissions, or if the rate of degradation over time of the rubberized asphalt and the concrete noise reduction treatments affects tire wear and PM-10 emissions rates. As such, consideration should be given to conducting research on those topics. The different concrete pavement surface test sections that currently exist on Loop 101, along with rubberized asphalt overlays of different ages throughout the Valley, provide locations where such research could be conducted.

2 INTRODUCTION

2.1 Noise and Decibels

Noise volume is measured in decibels. A correct understanding of the magnitude of change between different decibel levels is critical to understanding the effectiveness of different freeway noise reduction treatments. Noise decibels (denoted "dBA") use a base-two A-weighted logarithmic (i.e., inverted exponential) scale with the percentage change in noise volume determined by the following equation:

$$\text{Percentage change in noise volume} = (2^{(\text{change in decibels}/10)} - 1) * 100$$

This means noise volume doubles with every 10-decibel increase in volume. Most humans don't perceive much of a change in noise volume below three decibels. **Table 1** shows how the percentage change in noise volume corresponds to decibel changes:

Table 1 – Decibel Noise Level Changes

Decibel (dBA) Change	Percentage Change in Noise Volume
1 dBA	7%
2 dBA	15%
3 dBA	23%
4 dBA	32%
5 dBA	41%
6 dBA	52%
7 dBA	62%
8 dBA	74%
9 dBA	87%
10 dBA	100%

For context, the decibel levels of common noises have been listed below:

- 60 dBA: conversational speech;
- 70 dBA: vacuum cleaner;
- 80 dBA: garbage disposal;
- 90 dBA: motorcycle at 25 feet;
- 100 dBA: jackhammer;
- 110 dBA: live rock music;
- 120 dBA: thunderclap; and
- 130 dBA: military jet takeoff at 50 feet.

2.2 Early Freeway Noise Complaints

Prior to the early 2000s, the primary surface texture treatment used nationally on concrete pavement freeways was uniform transverse tining, which is a method of cutting grooves at regular intervals into the concrete surface perpendicular to the direction of travel to improve the friction of the surface. Transverse tining, however, generates undesirably high noise levels from tire whine. The noise levels of the concrete freeways led to citizen complaints, which the Arizona Department of Transportation (ADOT) responded to by evaluating alternative quieter freeway pavement surface treatment techniques.

The two alternative freeway concrete pavement surface treatments showing the most potential for improved friction and noise reduction from a preliminary analysis conducted by ADOT were:

- Longitudinal tining (cutting grooves parallel to the direction of travel); and
- Asphalt rubber asphaltic concrete friction course (AR-ACFC) (i.e., rubberized asphalt or quiet pavement).

The longitudinal tining produced a noise reduction upon installation of 4 dBA - 5 dBA compared to transverse tining. The rubberized asphalt overlay produced a noise reduction upon installation of 7 dBA - 10 dBA compared to transverse tining. While the rubberized asphalt overlay produced a higher noise reduction upon installation compared to longitudinal tining, as the pavement treatment wore down, it was noted that the rubberized asphalt overlay noise levels increased at a higher rate than the longitudinal tining noise levels over time.

2.3 Quiet Pavement Pilot Program

In response to citizen complaints and based on the preliminary rubberized asphalt noise reduction results upon installation, Governor Jane Hull mandated in early 2003 that ADOT cover all transversely tined freeway concrete pavement with a rubberized asphalt overlay. Today, almost all of the region's urban freeway mainline system has a rubberized asphalt overlay (exceptions being most of SR-143 and SR-303L between I-17 and Happy Valley Pkwy). Rubberized asphalt is currently included as a project scope item for new and reconstruction freeway projects funded through the Freeway Life-Cycle Program (FLCP) as part of Proposition 400, the Maricopa County half-cent sales tax for transportation improvements.

Soon after Governor Hull's rubberized asphalt mandate, ADOT initiated a Quiet Pavement Pilot Program (QPPP) using research funding to research the long-term noise reduction benefits of AR-ACFC/rubberized asphalt as an overlay on existing concrete freeways. The pilot program compared tire whine noise produced by the transversely tined concrete pavement to the noise produced by a rubberized asphalt overlay at the same locations on five different freeways (I-10, I-17, SR-51, SR-101L, and SR-202L). Research results showed that when first installed, the rubberized asphalt noise level was typically 96 dBA - 98 dBA, which compared favorably to the typical transversely tined noise level of 104 dBA - 108 dBA, an average noise reduction of approximately 75% - 100%. At the end of the 12-year program, however, the rubberized asphalt noise level was typically 102 dBA - 104 dBA, a noise reduction of only 15% - 30% compared to transversely tined concrete, indicating noise levels increased by approximately 0.5 dBA per year.

The pilot program also measured noise levels 50 feet from the freeway and in the neighborhoods adjacent to the freeway. Noise reductions of 5 dBA - 9 dBA (40% - 90%) were measured throughout the 12-year life of the pilot program, suggesting that the noise reduction benefits from the rubberized asphalt are greater beyond the freeway than on the freeway.

2.4 Freeway Pavement Noise Reduction Treatments – Where do we go from here?

Funding for rubberized asphalt overlays as part of new freeway construction in Maricopa County is typically funded by the Proposition 400 FLCP (county sales tax). Maintenance of the rubberized asphalt overlay is typically funded through the National Highway Trust Fund (federal gas tax) and Highway User Revenue Fund (state gas and vehicle license/registration tax). The combination of aging infrastructure and more fuel-efficient/electric vehicles has resulted in insufficient funding to adequately construct and maintain roadways in a good state of repair.

The typical life cycle of a rubberized asphalt overlay is 10 years. Almost all of the existing rubberized asphalt in the Phoenix metropolitan area is either overdue, or will soon be due, for replacement.

There is one funded project to replace the rubberized asphalt (on I-10 between Avondale Boulevard and I-17) in ADOT's most recent five-year construction program. The rubberized asphalt is also planned to be replaced on portions of I-10, I-17, SR-101L, and SR-202L as part of major Proposition 400 widening/reconstruction projects, but many of these projects are five to ten years out. For the rest of the region's freeway system, there is currently no identified funding to replace and maintain the rubberized asphalt.

This document assesses options moving forward regarding freeway pavement noise reduction treatments in light of the projected funding shortfall. More detailed information on the existing condition of the freeway system and potential alternatives to rubberized asphalt is provided in subsequent sections.

3 EXISTING FREEWAY PAVEMENT CONDITIONS

3.1 Age of Rubberized Asphalt Overlay

Figure 1 shows when the current rubberized asphalt overlay was constructed based on a combination of sources provided by ADOT and MAG in 2019 along with aerial photography. This map assumes a baseline year of 2020 and includes the completion of ongoing widening projects along SR-101L and the completion of the South Mountain portion of SR-202L.

Rubberized asphalt is assumed to typically have a 10-year service life. Approximately 50% of the existing rubberized asphalt overlay is older than 10 years, with some segments of I-17, SR-51, SR-101L, and SR-202L having an age of 15 to 17 years. A more detailed breakdown of the rubberized asphalt overlay age is provided in **Appendix A**.

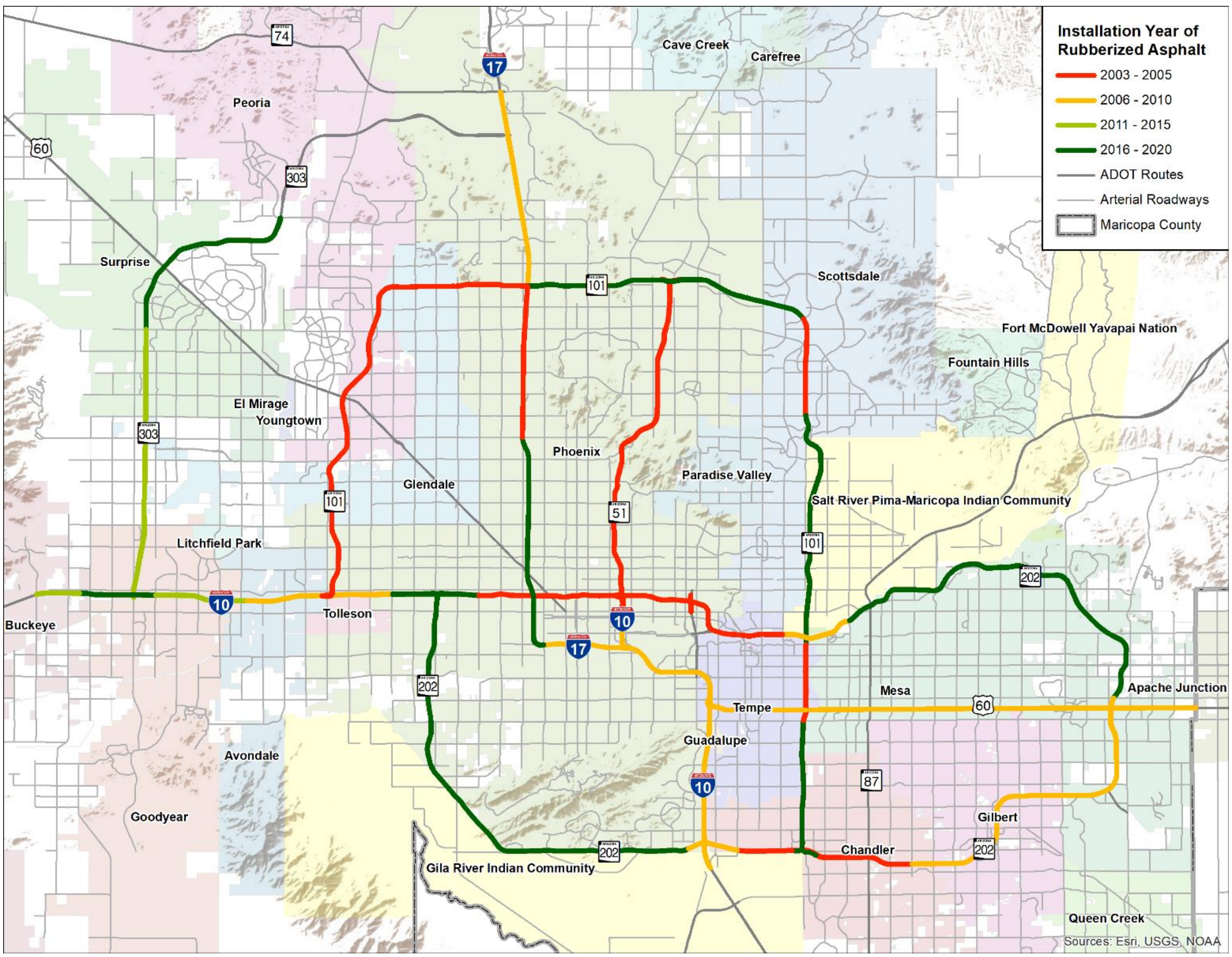


Figure 1 – Age of Rubberized Asphalt Overlay

3.2 Existing Rubberized Asphalt Overlay Condition

ADOT provided pavement condition data collected in 2018 in tenth-of-a-mile increments on three metrics for measuring the condition of rubberized asphalt throughout the region:

- **Surface roughness** – measured using the International Roughness Index (IRI), which is calculated as the accumulated suspension motion (movement up and down) divided by the distance of the segment;
- **Pavement cracking** – calculated as the percentage of the pavement that is cracked; and
- **Pavement rutting** – the depth of the rut in the wheelpath of the travel lane.

A detailed analysis of the rubberized asphalt overlay condition for all three metrics is provided in **Appendix B**.

Roughness (IRI)

ADOT has set the following IRI thresholds for when pavement is in good (or satisfactory) condition, fair (or tolerable) condition, and poor (or objectionable) condition:

- **Good**: IRI of 0 - 75 for interstates and 0 - 93 for non-interstates;
- **Fair**: IRI of 76 - 104 for interstates and 94 - 142 for non-interstates; and
- **Poor**: IRI of >105 for interstates and >143 for non-interstates.

Figure 2 shows the condition of the rubberized asphalt around the region based on the IRI. The IRI values were averaged across adjacent segments of rubberized asphalt applied in the same year. Based on the IRI thresholds provided above, most of the rubberized asphalt within the region is in 'Good' condition. Isolated segments of I-10, I-17, SR-143, and SR-202L are in 'Fair' condition. No segments are in 'Poor' condition based on their average IRI values.

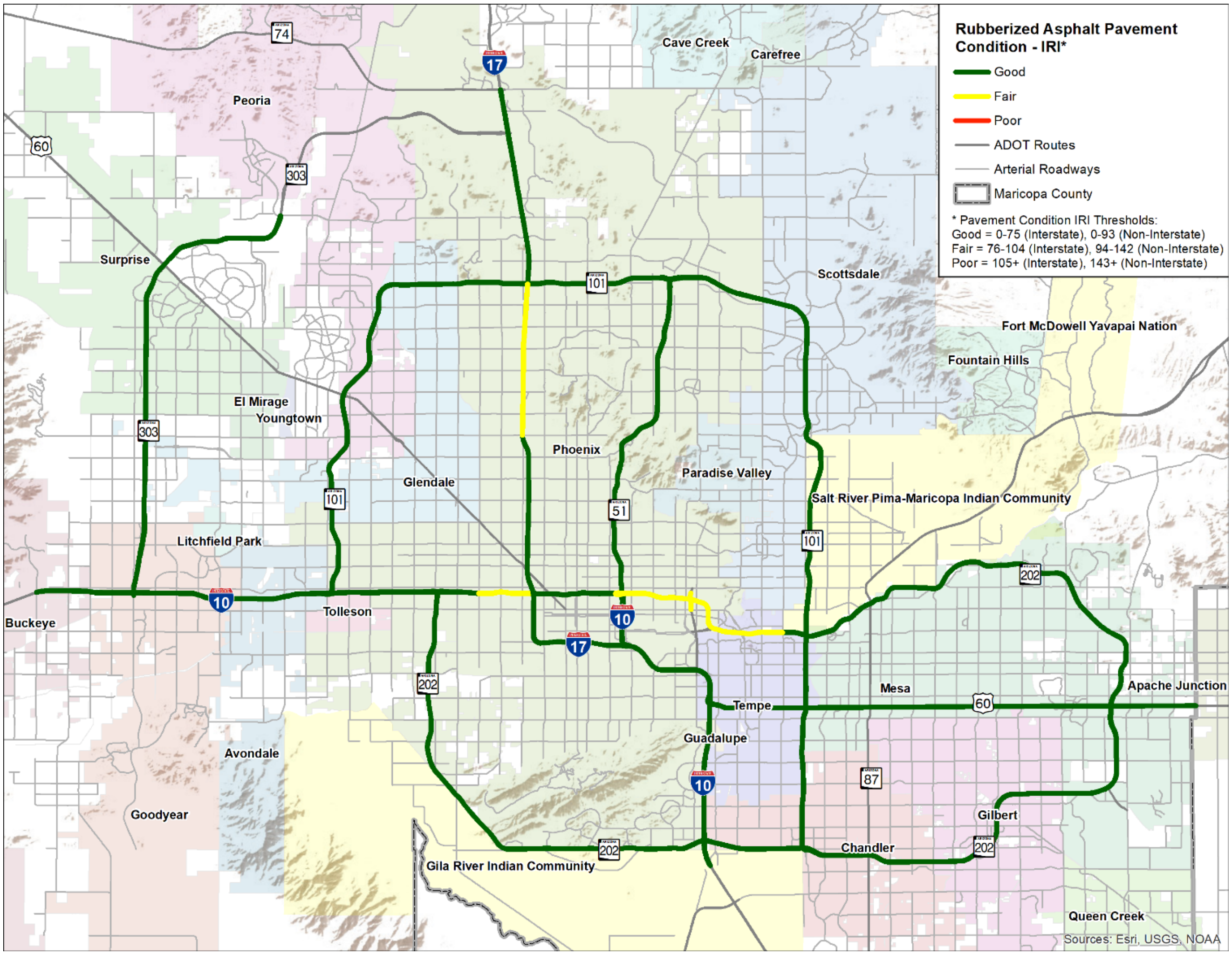


Figure 2 – Rubberized Asphalt Pavement 2018 Condition Based on Roughness (IRI)

Cracking

Thresholds developed by ADOT for pavement cracking are:

- **Good**: <5% cracking;
- **Fair**: 5% - 10% cracking; and
- **Poor**: >10% cracking.

Figure 3 shows the condition of the rubberized asphalt based on cracking. Similar to the roughness calculation, cracking was averaged across adjacent segments of rubberized asphalt applied in the same year. Three segments have greater than 10% average cracking and are in 'Poor' condition: I-17 between Dunlap Avenue and SR-101L (Agua Fria), SR-101L (Price) between SR-202L (Red Mountain) and US-60, and SR-202L (Santan) between Kyrene Road and McClintock Drive. Many additional rubberized asphalt segments are rated in 'Fair' condition based on cracking.

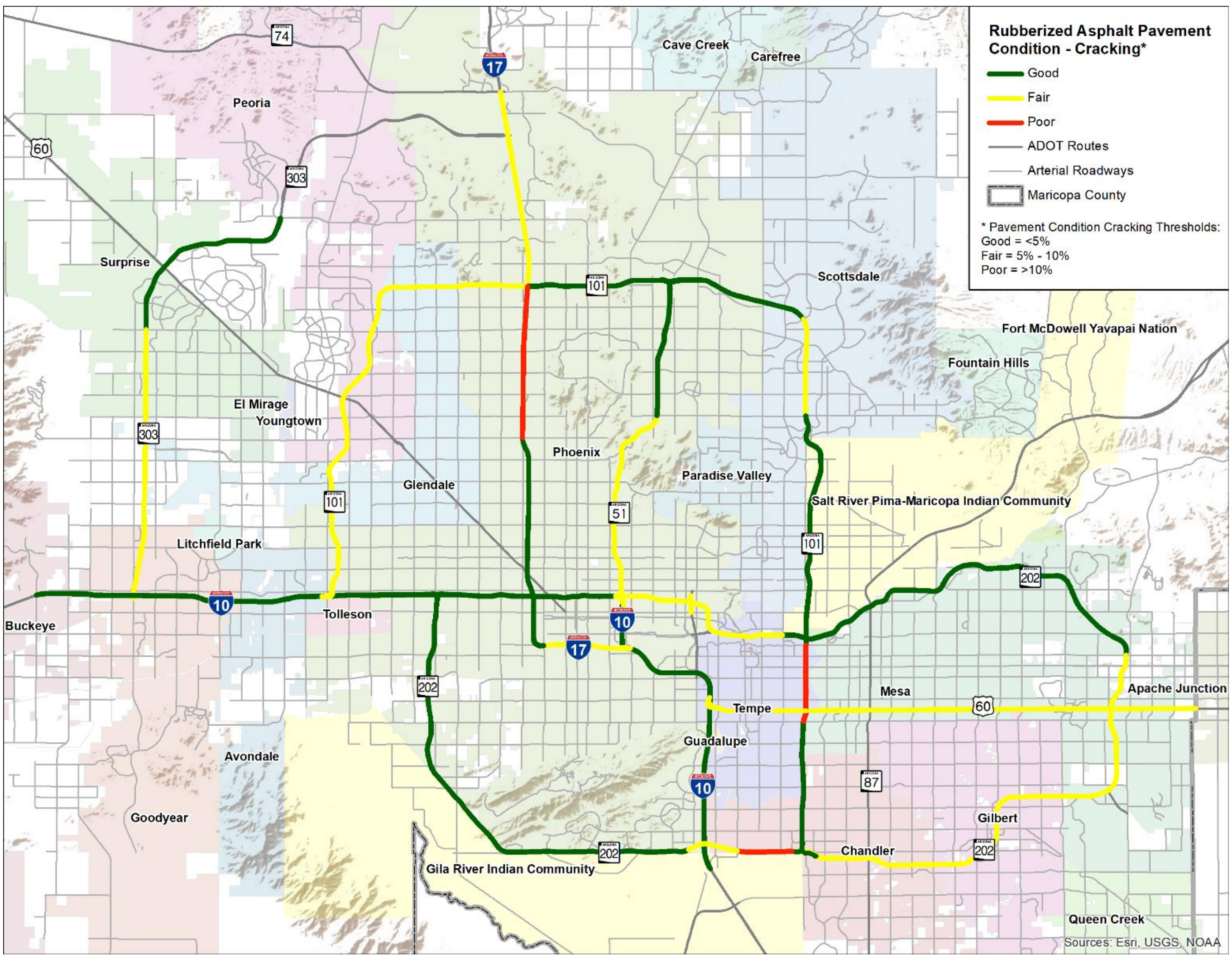


Figure 3 – Rubberized Asphalt Pavement 2018 Condition Based on Cracking

Rutting

Thresholds developed by ADOT for pavement rutting are:

- **Good**: <0.2 inches;
- **Fair**: 0.2 – 0.4 inches; and
- **Poor**: > 0.4 inches.

Figure 4 shows the condition of the rubberized asphalt based on rutting. Similar to the roughness and cracking calculations, rutting was averaged across adjacent segments of rubberized asphalt applied in the same year. Based on the provided rutting data, all rubberized asphalt segments are rated as 'Good'.

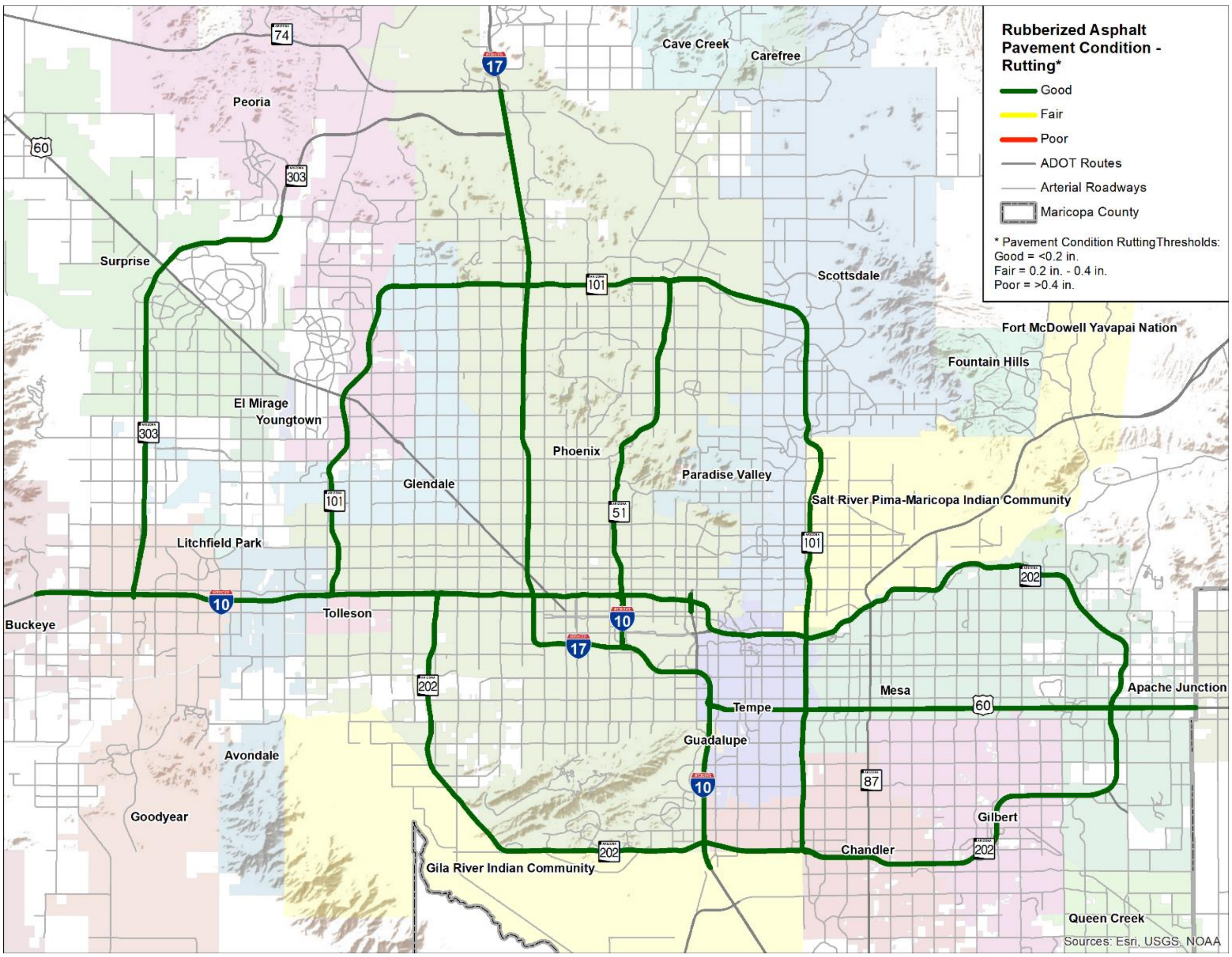


Figure 4 – Rubberized Asphalt Pavement 2018 Condition Based on Rutting

Percentage of Failing Pavement

To combine the three pavement condition metrics into one analysis, any tenth-of-a-mile increment that rated as 'Poor' by any of the three metrics (>105 IRI on interstates, >143 IRI on non-interstates, >10% cracking, or >0.4 inches of rutting) was flagged as 'failing'. The percentage of 'failing' tenth-of-a-mile increments across adjacent segments of rubberized asphalt applied in the same year was calculated.

Figure 5 shows the results of this analysis. Several segments of rubberized asphalt, totaling approximately 13.3 centerline miles, have greater than 50% of the pavement 'failing' by at least one of the three pavement condition metrics, including:

- I-17 between Dunlap Avenue and SR-101L (Agua Fria);
- SR-101L (Price) between SR-202L (Red Mountain) and US-60; and
- SR-202L (Santan) between Kyrene Road and McClintock Drive.

Several additional segments, totaling approximately 43.9 centerline miles, have between 25% and 50% of the pavement 'failing' by at least one of the three pavement condition metrics:

- I-10 between 43rd Avenue and I-17;
- I-17 between I-10 (Split Interchange) and 19th Avenue;
- SR-51 between I-10 and Shea Boulevard;
- SR-101L (Agua Fria) between Union Hills Drive and I-17;
- SR-143 between Van Buren Street and Belleview Street;
- SR-202L (Santan) between 48th Street and Kyrene Road; and
- US-60 between I-10 and Crismon Road.

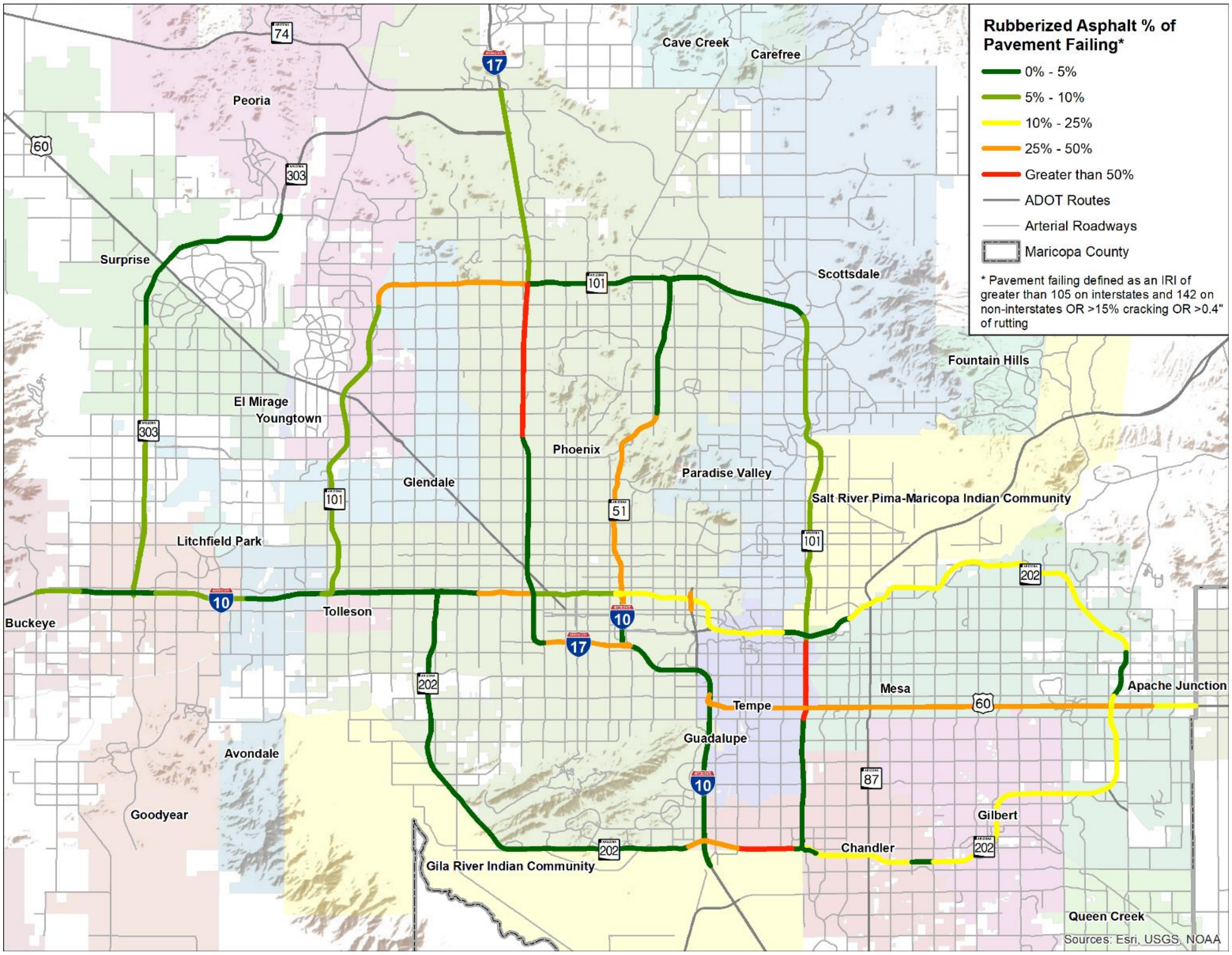


Figure 5 – Percentage of 'Failing' Rubberized Asphalt Pavement in 2018 by Freeway Segment

3.3 Age of Subbase

Rubberized asphalt overlays were constructed on top of existing freeway concrete and subbase. The condition of the subbase may have impacts on the service life of the rubberized asphalt overlay if it has deteriorated.

Figure 6 shows the decade in which the subbase for each freeway segment was constructed. The subbase age for each freeway segment was inferred from the ADOT bridge inventory; this analysis assumes that if a freeway's subbase was reconstructed or replaced, the bridges would also have been replaced.

Most freeway corridors were initially constructed between the 1980s and 2000s, though some segments of I-10, I-17, and US-60 were constructed before 1980.

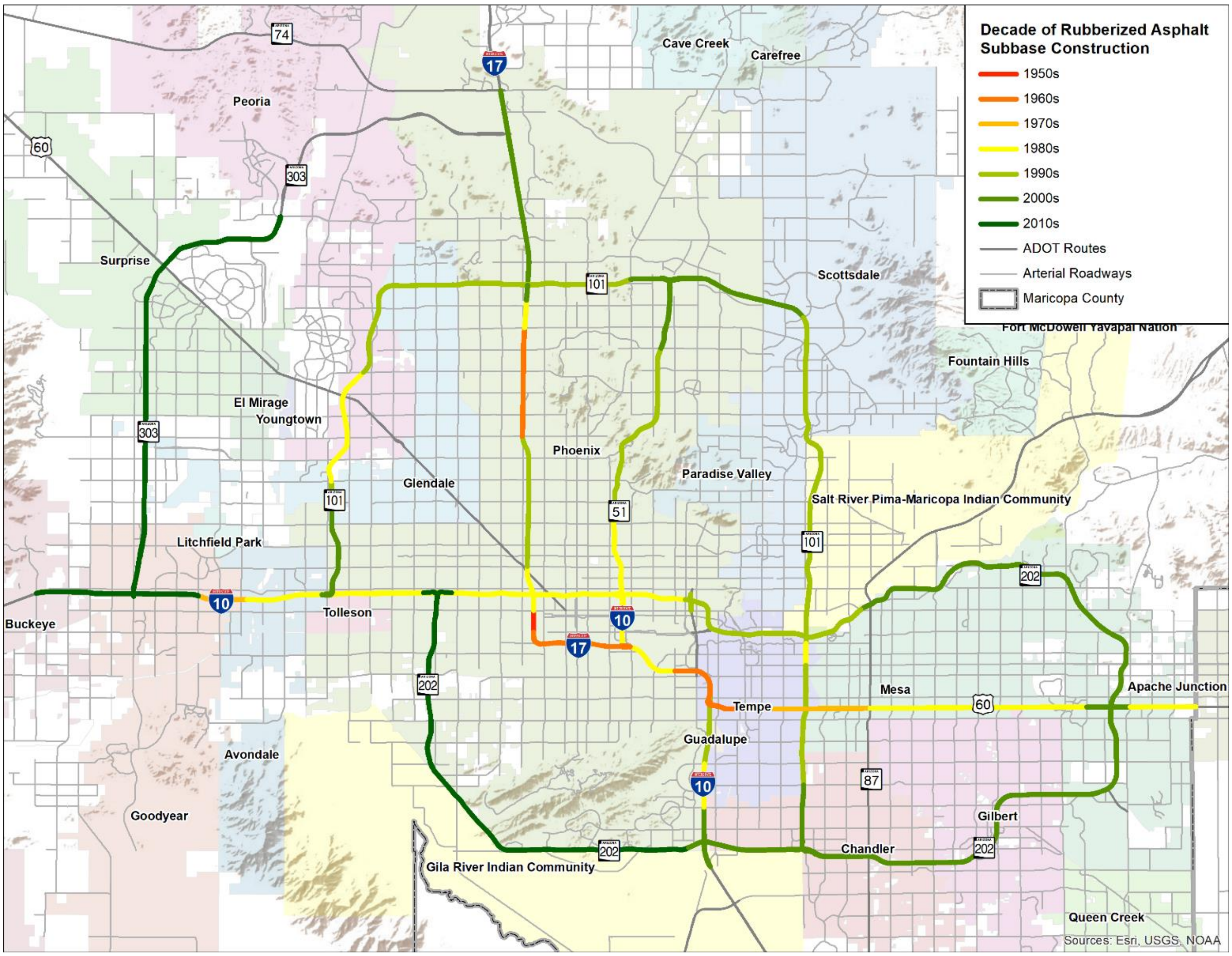


Figure 6 – Rubberized Asphalt Subbase Age

3.4 Rubberized Asphalt Overlay Replacement Priorities

Approximately 129.3 centerline miles of rubberized asphalt overlay have been in place longer than the expected 10-year service life. Recommendations for the prioritization of rubberized asphalt overlay replacement throughout the region have been developed based on the previous analyses within this chapter. The replacement priorities have been broken down into three prioritization levels:

- **High-Priority Replacement Need:** Pavement failure percentage of greater than 25%;
- **Moderate-Priority Replacement Need:** Pavement failure percentage between 10% and 25% **or** the rubberized asphalt is beyond its 10-year service life; and
- **Low-Priority Replacement Need:** Pavement failure of less than 10% **and** the rubberized asphalt surface is within the 10-year service life.

The rubberized asphalt overlay replacement priorities are presented geographically in **Figure 7**.

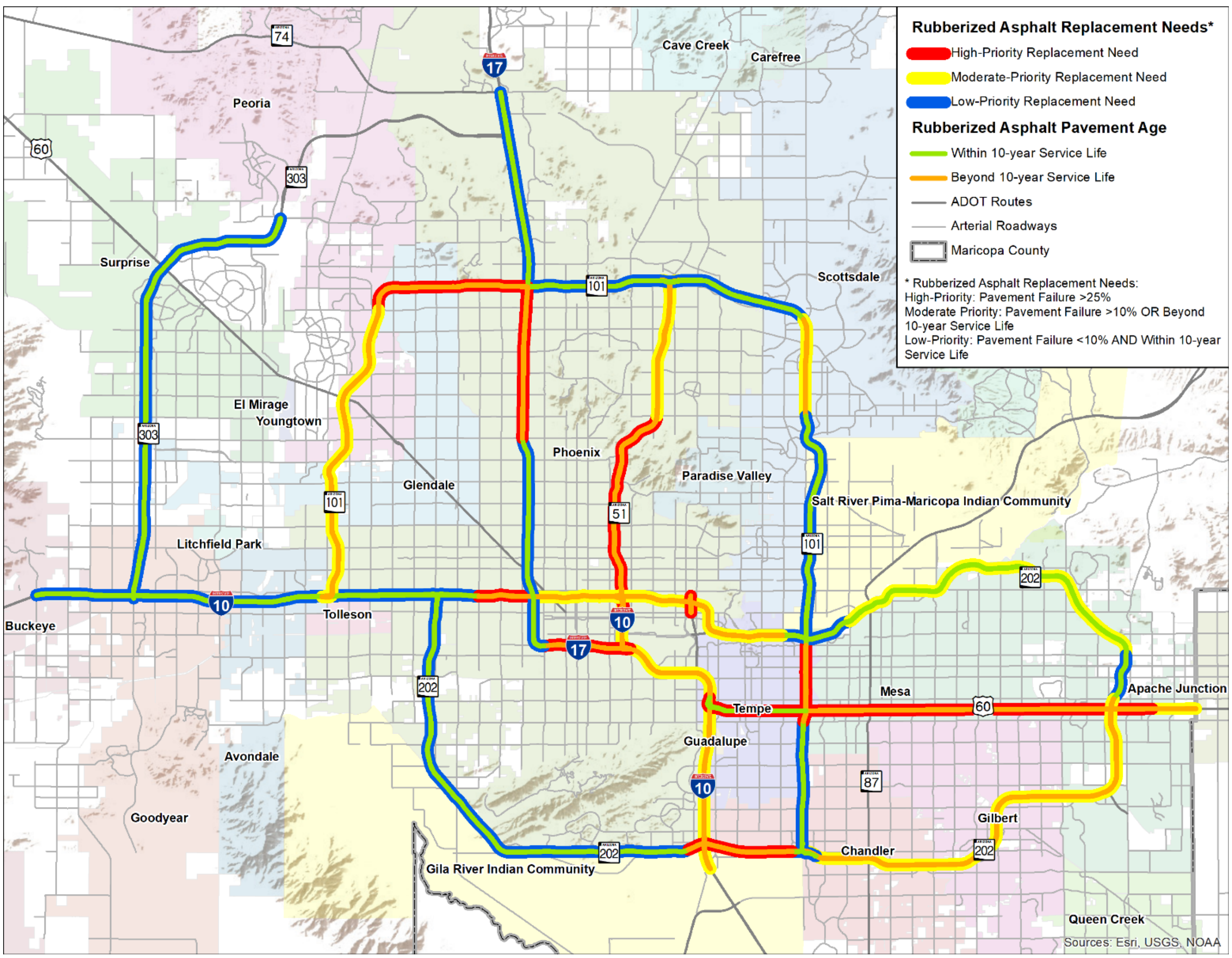


Figure 7 – Rubberized Asphalt Replacement Needs

As was mentioned previously, there are existing planned and programmed improvements for specific corridors within the urban freeway system. These improvements are funded through the Proposition 400 sales tax and are shown in **Figure 8** along with the fiscal year (FY) in which improvements are programmed. These projects include widening for additional general-purpose lanes (GPL), widening for high-occupancy vehicle (HOV) lanes, and widening to add auxiliary lanes. There is also one rubberized asphalt replacement project in the ADOT five-year construction program. It is recommended, as part of those projects, that the rubberized asphalt overlay be replaced in kind or with another more cost-effective pavement noise reduction treatment, as the rubberized asphalt has either already surpassed its 10-year service life (or will soon) or there is a high percentage of 'failing' pavement.

As shown in the previously referenced **Figure 7**, the locations of high-priority rubberized asphalt replacement needs are:

- I-10 between 43rd Avenue and I-17 (programmed to be resurfaced in FY 2021);
- I-17 between I-10 (Split Interchange) and 19th Avenue (programmed to be widened for auxiliary lanes in FY 2027);
- I-17 between Dunlap Avenue and SR-101L (Agua Fria);
- SR-51 between I-10 and Shea Boulevard;
- SR-101L (Agua Fria) between Union Hills Drive and I-17 (programmed to be widened with general purpose lanes in FY 2026);
- SR-101L (Price) between SR-202L (Red Mountain) and Baseline Road;
- SR-143 between Van Buren Street and Belleview Street;
- SR-202L (Santan) between McClintock Drive and 48th Street (programmed to be widened with general purpose lanes in FY 2030); and
- US-60 between I-10 and Crismon Road.

Several of these segments have a subbase constructed several decades ago, where the subbase and concrete will need to be evaluated to determine if they need to be replaced or rehabilitated to avoid negatively impacting the service life of the pavement noise reduction treatment. Segments of most concern are:

- I-17 between Dunlap Avenue and SR-101L (Agua Fria) – much of the subbase along this section was constructed in the 1960s;
- US-60 between I-10 and SR-101L (Price) – the subbase along this segment was constructed in the 1960s and 1970s; and
- US-60 between SR-101L (Price) and SR-87 – the subbase along this segment was constructed in the 1970s.

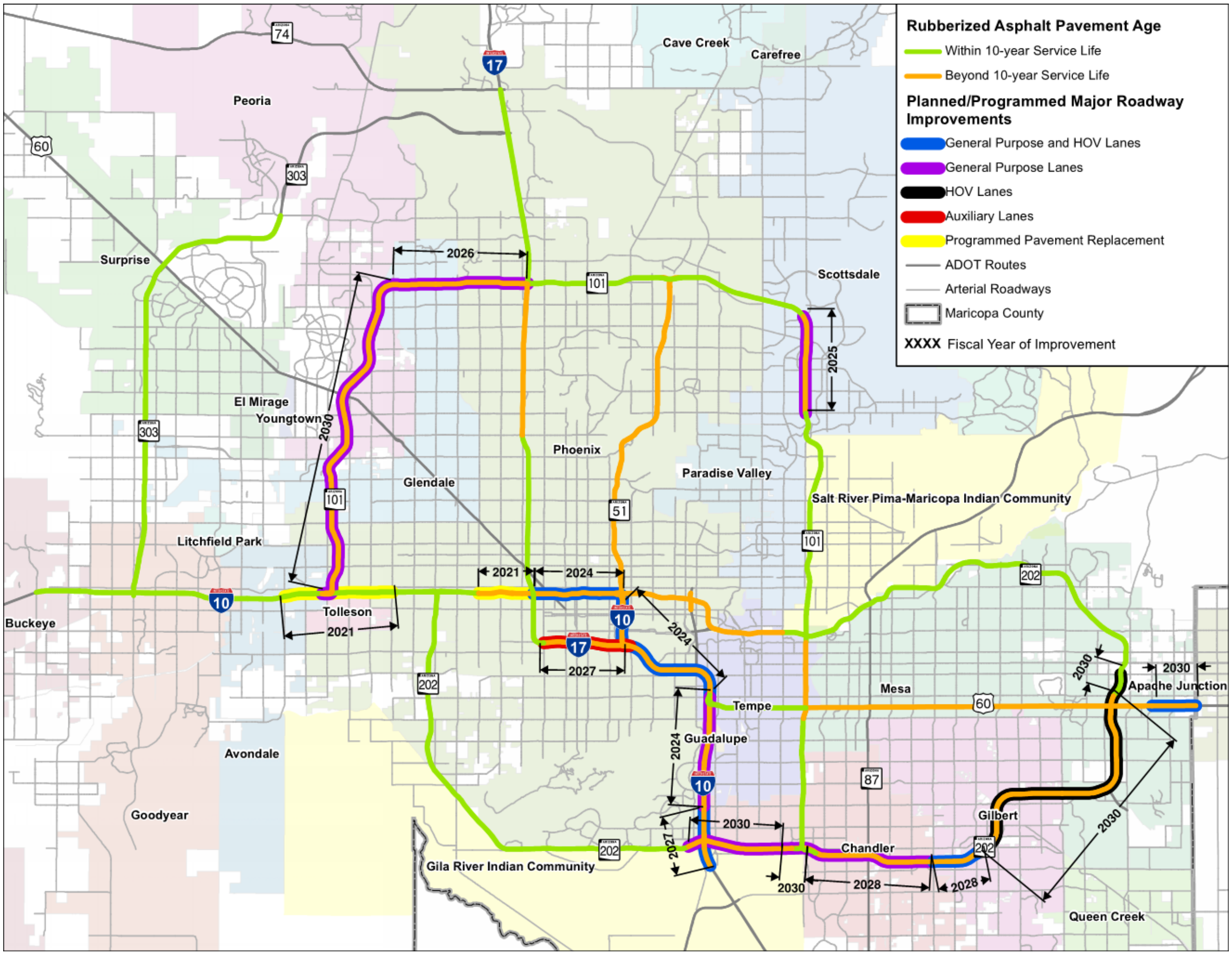


Figure 8 – Planned/Programmed Major Roadway Improvements

4 FREEWAY NOISE REDUCTION TREATMENT ALTERNATIVES

Rubberized asphalt is a freeway noise reduction treatment typically expected to last up to 10 years. As the service life of the rubberized asphalt comes to an end, a decision needs to be made whether to replace the rubberized asphalt surface or utilize an alternative freeway noise reduction treatment.

4.1 Pavement Treatment Comparison

There are two primary pavement surface treatment types used on freeways – concrete and asphalt. Concrete and asphalt treatments were compared generally in the following five categories:

- Noise Level;
- Life-Cycle Cost;
- Road Smoothness;
- Aesthetics; and
- Environmental Impacts.

Table 2 summarizes the advantages and disadvantages of concrete and asphalt pavement surface treatments.

Table 2 – Concrete and Asphalt Surface Comparison

Surface Attribute	Concrete Surface	Asphalt Surface
Noise Level	**Advantage**: Little change over time **Disadvantage**: Typically higher than asphalt initially	**Advantage**: Typically lower initially than concrete **Disadvantage**: Increases over time, ultimately being equal to or higher than concrete
Life-Cycle Cost	**Advantage**: Lower than asphalt over service life **Disadvantage**: Typically higher than asphalt initially	**Advantage**: Typically lower than concrete initially **Disadvantage**: Higher than concrete over service life
Road Smoothness	**Advantage:** Little change over time **Disadvantage**: Has expansion cracks from heat/cold cycles	**Advantage**: Has no expansion cracks **Disadvantage**: Raveling and cracking increase over time, especially when traffic volumes are high or there are many heavy vehicles (trucks)
Aesthetics	**Advantage**: Little change over time **Disadvantage**: Hard to see white pavement markings unless provide black outline of markings on white concrete surface	**Advantage**: Easy to see white pavement markings on dark asphalt surface **Disadvantage**: Deteriorates over time
Environmental Impacts	**Advantage**: Cooler than asphalt during the day **Disadvantage**: Hotter than asphalt at night; cannot easily be recycled	**Advantage**: Cooler than concrete at night; can easily be recycled; provides slight reduction in PM-10 emissions compared to untreated concrete[1]. **Disadvantage**: Hotter than concrete during the day

1. The MAG 2012 Five Percent Plan for PM-10 for the Maricopa County Nonattainment Area indicates that, based on data provided by ADOT and Arizona State University, rubberized asphalt provides a PM-10 emission reduction of 0.034 tons/lane-mile/year (assuming 17,000 vehicles/lane/day). This represents a 30%-50% reduction in tire wear emissions with rubberized asphalt compared to untreated concrete; tire wear emissions represent less than 1% of overall emissions.

For asphalt, the primary freeway noise reduction treatment is rubberized asphalt – what the region currently uses. For concrete, three potential viable alternatives for pavement treatments are: diamond grind, whisper grind, and Skidabrader. **Table 3** summarizes the application process for these four pavement treatment alternatives.

Table 3 – Freeway Noise Reduction Treatment Alternatives Application Process Summary

Treatment	Application Process
Rubberized Asphalt	Apply rubberized asphalt overlay to existing concrete or asphalt pavement surface.
Diamond Grind	Use a diamond saw blade to cut shallow grooves in the pavement with small fins extending above the surface between the grooves.
Whisper Grind	Use a diamond saw blade to cut deeper longitudinal grooves into the pavement.
Skidabrader	Fire steel ball bearings into pavement surface and then collect and recycle.

All four of these freeway noise reduction treatment alternatives provide similar levels of improved surface friction compare to untreated asphalt or concrete. More detailed information is available on each treatment alternative in subsequent subsections. Lane-mile costs provided in subsequent subsections include rubberized asphalt removal, materials, traffic control, pavement markings, engineering, contingency, and Indirect Cost Allocation Plan (ICAP).

4.2 Rubberized Asphalt Treatment

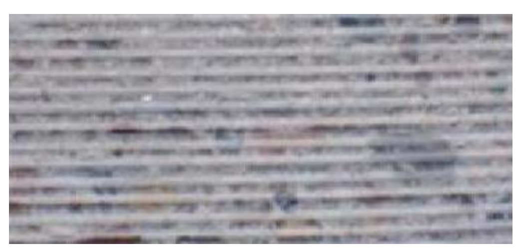
Rubberized asphalt treatment is an overlay applied over asphalt or concrete (see **Figure 9**). Besides reducing noise, it also protects the underlying asphalt or concrete. Rubberized asphalt typically produces around 97 dBA at installation and around 103 dBA at the end of service life. Noise levels increase by approximately 0.5 dBA per year as the rubberized asphalt pavement surface is worn down by traffic. Rubberized asphalt typically lasts 10 years with minimal maintenance required. Rubberized asphalt is estimated to typically cost $116,000 per lane mile based on 2019 cost data provided by ADOT.

Source: Arizona Department of Transportation

Figure 9 – Rubberized Asphalt Treatment Photo

4.3 Diamond Grind Treatment

Diamond grind treatment uses diamond saw blades to create shallow grooves in the pavement with small fins extending above the surface between the grooves (see **Figure 10**). Diamond grind typically produces around 102 dBA at installation and around 103 dBA at the end of service life. Noise levels increase only slightly over time with diamond grinding as the fins are worn down by traffic. Diamond grind typically lasts 15 years and a concrete surface can be diamond ground up to three times without replacement of the concrete surface. Diamond grind is estimated to typically cost $123,000 per lane mile based on 2019 cost data provided by ADOT.

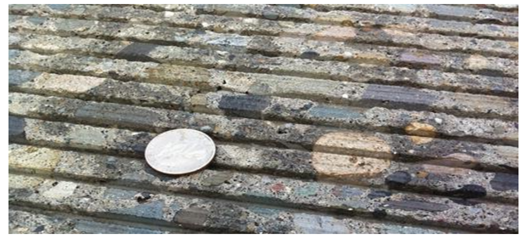


Source: International Grooving and Grinding Association

Figure 10 – Diamond Grind Treatment Photo

4.4 Whisper Grind Treatment

Whisper grind treatment – also known as Next Generation Concrete Surface (NGCS) – uses the same equipment as diamond grinding to grind deeper longitudinal grooves into the pavement surface (see **Figure 11**). Whisper grind initially yields a smoother, quieter surface than conventional diamond grinding. Whisper grind typically produces around 100 dBA at installation and around 103 dBA at the end of service life. Noise levels increase by approximately 0.25 dBA per year as the grooves are worn down by traffic. Whisper grind typically lasts 15 years and a concrete surface can be diamond ground up to three times without replacement of the concrete surface. Whisper grind is estimated to typically cost $150,000 per lane mile based on 2019 cost data provided by ADOT.



Source: Washington State Department of Transportation

Figure 11 – Whisper Grind Treatment Photo

4.5 Skidabrader Treatment

The Skidabrader treatment (see **Figure 12**), also known as shot-blasting, fires steel ball bearings at the pavement surface, which are then collected and recycled. Skidabrader is a more cost-effective surface treatment for improving friction than the other three alternatives but produces noise levels similar to untreated concrete of around 104 dBA at installation and around 106 dBA at the end of service life. Skidabrader treatment is estimated to typically cost $90,000 per lane mile based on 2019 cost data provided by ADOT.

Source: Shot Blast, Inc.

Figure 12 – Skidabrader Treatment Photo

4.6 Summary of Pavement Noise Reduction Treatment Alternatives

Figure 13 summarizes the typical pavement surface noise levels at construction and end of service life for untreated asphalt, untreated concrete, and for the four analyzed alternatives. The rubberized asphalt, diamond grind, and whisper grind treatments all show reductions in noise levels compared to untreated concrete, with the effectiveness of that noise reduction decreasing over time, particularly for the rubberized asphalt. Skidabrader does not reduce noise levels.

The rubberized asphalt produces the lowest noise level at installation (97 dBA) of the four treatment alternatives but increases in noise level over time to the point where it has a similar noise level at the end of service life (103 dBA) as the diamond grind and whisper grind concrete treatments. It is important to note the rubberized asphalt has a 10-year service life while the concrete treatments have a 15-year service life.

The diamond grind produces the highest noise level at installation (102 dBA) of the treatment alternatives that reduce noise but remains relatively constant over time such that the noise level at the end of service life (103 dBA) is similar to the rubberized asphalt and whisper grind treatments.

The whisper grind produces the lowest noise level at installation (100 dBA) of the three concrete treatment alternatives but increases in noise level over time to the point where it has a similar noise level at the end of service life (103 dBA) as the rubberized asphalt and diamond grind treatments.

With 3 dBA being the minimum noise difference most humans can hear, rubberized asphalt provides a significant improvement in noise reduction over diamond grind, whisper grind, and Skidabrader for approximately the first half of their respective service lives (i.e., the first 5-7 years). For the second half of their service lives, there is no significant difference in noise reduction between rubberized asphalt, diamond grind, and whisper grind, but all three do have a significant improvement in noise reduction of at least 3 dBA compared to untreated concrete.

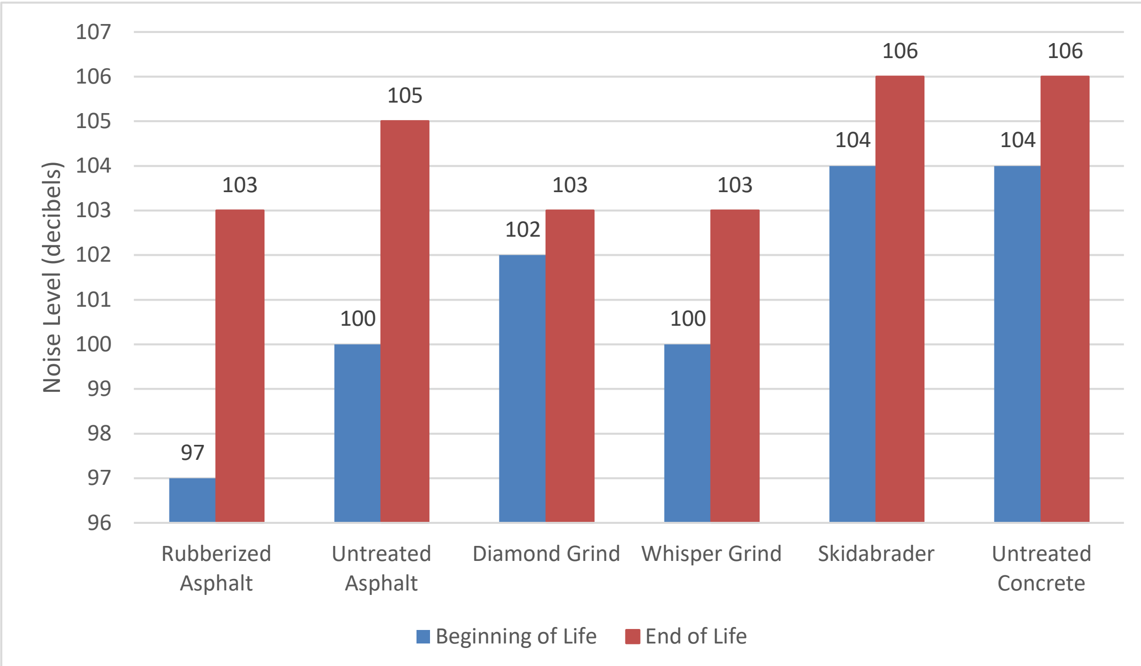


Figure 13 – Typical Pavement Surface Noise Level over Service Life

Table 4 summarizes the noise levels, life span, and planning-level cost estimates for the pavement noise reduction treatment alternatives. More information on the cost estimates is provided in **Appendix C**.

Table 4 – Noise Levels, Life Span, and Costs for Pavement Noise Reduction Treatment Alternatives

Pavement Noise Reduction Treatment	Typical Noise at Beginning of Service Life (dBA)	Typical Noise at End of Service Life (dBA)	Life Span (years)	Costs[1]			
				Per Lane Mile	Corridor[2]	Life-Cycle Corridor[3]	Life-Cycle System[4]
Rubberized Asphalt	97	103	10	$116,000	$9,280,000	$41,760,000	$1,239,901,000
Diamond Grind	102	103	15	$123,000	$9,840,000	$29,520,000	$912,784,000
Whisper Grind	100	103	15	$150,000	$12,000,000	$36,000,000	$1,098,290,000
Skidabrader	104	106	15	$90,000	$7,200,000	$21,600,000	$686,054,000

1. Bridge joint replacement work is included in the diamond grind, whisper grind, and Skidabrader cost estimates.
2. Corridor costs based on a new 10-mile, eight-lane section (four lanes in each direction) with auxiliary lanes and shoulders.
3. Life-cycle costs based on corridor costs over a period of 25 years.
4. System costs based on maintenance and construction cost of the treatment for the entirety of the freeway system that currently has rubberized asphalt over a period of 25 years.

5 RECOMMENDED PAVEMENT NOISE REDUCTION TREATMENT

Each of the four pavement noise reduction treatment alternatives has advantages and disadvantages. The scenarios where each treatment alternative would likely be the preferred treatment are described below:

- **Rubberized asphalt**: appropriate treatment where noise reduction is a much higher priority than cost-effectiveness and where replacement of the rubberized asphalt will occur every 6 years to maintain a significant level of noise reduction; rubberized asphalt is the least cost-effective treatment alternative from a life-cycle cost perspective of the three alternatives that reduce noise;
- **Diamond grind**: appropriate treatment where noise reduction and cost-effectiveness are both priorities and where replacement of the diamond grind treatment will occur every 15 years to maintain a significant level of noise reduction; diamond grind is the most cost-effective treatment alternative from a life-cycle cost perspective at reducing noise;
- **Whisper grind**: appropriate treatment where noise reduction is a slightly higher priority than cost-effectiveness and where replacement of the whisper grind treatment will occur every 15 years to maintain a significant level of noise reduction; whisper grind is more cost-effective than rubberized asphalt but less cost-effective than diamond grind from a life-cycle cost perspective at reducing noise;
- **Skidabrader**: appropriate treatment where improving roadway surface friction and cost-effectiveness are both priorities and where replacement of the Skidabrader treatment will occur every 15 years to maintain a desirable level of surface friction; this treatment should not be considered if noise reduction is desired.

Considering the challenges the MAG region and state have had in recent years – and are projected to continue to have in the future – to secure adequate funding for roadway maintenance, consideration should be given to replacement of the rubberized asphalt overlay with a diamond grind treatment.

To date, there has only been limited research on how different pavement surface treatments affect tire wear and PM-10 emissions. Arizona State University conducted research in 2006 for ADOT in the Deck Park tunnel on I-10 that indicated newly installed rubberized asphalt reduced tire wear and PM-10 emissions compared to untreated concrete. No research documentation was available, however, related to how the different concrete noise reduction treatments (i.e., diamond grind, whisper grind, and Skidabrader) affect tire wear and PM-10 emissions, or if the rate of degradation over time of the rubberized asphalt and the concrete noise reduction treatments affects tire wear and PM-10 emissions rates. As such, consideration should be given to conducting research on those topics. The different concrete pavement surface test sections that currently exist on Loop 101, along with rubberized asphalt overlays of different ages throughout the Valley, provide locations where such research could be conducted.

6 REFERENCES

Information in this document was derived from the following sources:

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4. Arizona Department of Transportation, “Regional Freeway System Rubberized Asphalt Surfacing”, March 2009.
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APPENDIX A – Rubberized Asphalt Age and Programmed Improvements

Route	From	From MP	To	To MP	Assumed Existing Rubberized Asphalt Install Date	Notes from Aerial Photograph Review	Completed Prop. 400 Major Reconstruction Year (Type)	Planned Major Reconstruction Year (Type)
I-10	Verrado Way	120.2	191st St	122.2	**2011**		2011 (GPL)	
	191st St	122.5	Sarival Ave	126.7	**2016**		2016 (303 Interchange)	
	Sarival Ave	126.7	Dysart Rd	130	**2011**	Appears to have been widened/resurfaced in 2011	2010 (GPL/HOV); 2011 (GPL)	
	Dysart Rd	130	75th Ave	136.6	**2010**	Appears to have been widened/resurfaced in 2009	2010 (GPL/HOV Dysart to 101)	2021 Rubberized Asphalt Overlay Replacement (Avondale Blvd to 75th Ave)
	75th Ave	136.6	43rd Ave	140.6	**2019**	SR 202 interchange resurfacing	2019 (202 Interchange)	
	43rd Ave	140.6	I-17	143.2	**2005**			2021 Rubberized Asphalt Overlay Replacement
	I-17	143.2	Van Buren St	148	**2004**			2024 (GPL/HOV)
	Van Buren St	148	Southern Ave	155	**2008**		2008 (GPL 143 to Southern)	2024 (GPL/HOV)
	Southern Ave	155	Ray Rd	159.7	**2006**			2024 (GPL)
	Ray Rd	159.7	Wild Horse Pass Blvd	162.5	**2008**			2027 (GPL/HOV 202 to Riggs)
I-17	I-10	193.9	19th Ave	198	**2008**			2027 (AUX)
	19th Ave	198	AZ Canal Trail	208.2	**2017**	Appears to have been resurfaced in 2017		
	AZ Canal Trail	208.2	SR-101L	215	**2005**			
	SR-101L	215	SR-74	224.4	**2010**		2009 (GPL HOV 101 to Jomax); 2010 (GPL/HOV Jomax to 74)	
SR-51	I-10	0	Shea Blvd	9.4	**2004**			
	Shea Blvd	9.4	SR-101L	15.9	**2004**		2009 (HOV)	

Route	From	From MP	To	To MP	Assumed Existing Rubberized Asphalt Install Date	Notes from Aerial Photograph Review	Completed Prop. 400 Major Reconstruction Year (Type)	Planned Major Reconstruction Year (Type)
SR-101L	I-10	1.2	Union Hills Dr	15.7	**2005**		2011 (HOV)	2030 (GPL US 60 to Union Hills)
	Union Hills Dr	15.7	I-17	23.1	**2004**		2011 (HOV)	2030 (GPL Union Hills to 75th Ave); 2026 (GPL 75th Ave to I-17)
	I-17	23.1	Pima Rd	36.6	**2020**	Currently being widened/resurfaced	2011 (HOV)	2020 (GPL)
	Pima Rd	36.6	Shea Blvd	41	**2004**		2008 (HOV)	2025 (GPL)
	Shea Blvd	41	SR-202L (Red Mtn)	51	**2016**	Appears to have been widened/resurfaced in 2016	2008 (HOV); 2016 (GPL)	
	SR-202L (Red Mtn)	51	US-60	55	**2005**		2010 (HOV)	
	US-60	55	SR-202L (Santan)	62.2	**2020**	Currently being widened/resurfaced	2010 (HOV)	2021 (GPL)
SR-143	Van Buren St	2.7	Belleview St	3.4	**2004**			
SR-202L	SR-51	0	Van Buren St	4.2	**2004**		2010 (GPL)	
	Van Buren St	4.2	McClintock Dr	8.7	**2005**	Appears to have been widened/resurfaced in 2010	2010 (GPL)	
	McClintock Dr	8.7	Alma School Rd	12	**2010**	Appears to have been widened/resurfaced in 2010	2010 (GPL)	
	Alma School Rd	12	University Dr	27.9	**2016**	Appears to have been resurfaced in 2016	2015 (GPL/HOV)	
	University Dr	27.9	Southern Ave	30	**2016**	Appears to have been resurfaced in 2016	2015 (GPL/HOV University to Broadway)	2030 (HOV Broadway to Southern)
	Southern Ave	30	Gilbert Rd	44.5	**2006**			2030 (HOV); 2028 (GPL Val Vista to Gilbert)
	Gilbert Rd	44.5	Cooper Rd	45.5	**2006**	Appears to have been widened/resurfaced in 2012	2011 (HOV)	2028 (2 GPL)

Route	From	From MP	To	To MP	Assumed Existing Rubberized Asphalt Install Date	Notes from Aerial Photograph Review	Completed Prop. 400 Major Reconstruction Year (Type)	Planned Major Reconstruction Year (Type)
SR-202L	Cooper Rd	45.5	McClintock Dr	51.2	**2005**	Appears to have been widened/resurfaced in 2012	2011 (HOV)	2028 (2 GPL Cooper to 101); 2030 (GPL 101 to McClintock)
	McClintock Dr	51.2	Kyrene Rd	53.7	**2003**	Appears to have been widened/resurfaced in 2012	2011 (HOV)	2030 (GPL)
	Kyrene Rd	53.7	48th St	56	**2008**	Appears to have been widened/resurfaced in 2012	2011 (HOV)	2030 (GPL)
	48th St	56	I-10	78	**2019**	Currently being constructed		
SR-303L	I-10	104.4	Bell Rd	116.2	**2014**		2014 (New)	
	Bell Rd	116.2	Happy Valley Rd	125.2	**2016**		2014 (New); 2016 (60 Interchange)	
US-60	I-10	172.1	SR-101L	176.5	**2010**	Appears to have been widened/resurfaced in 2010	2010 (GPL)	
	SR-101L	176.5	Power Rd	188.4	**2007**		2007 (GPL/HOV Val Vista to Power)	
	Power Rd	188.4	Crismon Rd	192.4	**2007**			
	Crismon Rd	192.4	Maricopa Co Line	194.4	**2008**			2030 (GPL/HOV Crismon to Meridian)

APPENDIX B – Rubberized Asphalt Pavement Condition Data

Segment Data		Eastbound/Northbound				Westbound/Southbound				Bidirectional Average				
Route	**Segment**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	**Notes**
I-10	Verrado Way - 191st St	52.16	0.0706	2.0	4.5%	59.85	0.0733	4.3	8.7%	**56.01**	**0.0719**	**3.2**	**6.6%**	
	191st St - Sarival Ave	46.62	0.0701	0.7	0.0%	47.48	0.0646	0.6	0.0%	**47.05**	**0.0674**	**0.6**	**0.0%**	
	Sarival Ave - Dysart Rd	65.39	0.0904	4.8	9.1%	59.48	0.0716	3.9	3.0%	**62.44**	**0.0810**	**4.3**	**6.1%**	
	Dysart Rd - 75th Ave	71.99	0.0816	2.8	1.6%	66.39	0.0872	2.1	1.6%	**69.19**	**0.0844**	**2.5**	**1.6%**	
	75th Ave - 43rd Ave	82.98	0.1123	0.0	5.3%	75.84	0.1054	0.4	0.0%	**79.41**	**0.1088**	**0.2**	**2.6%**	Currently being resurfaced
	43rd Ave - I-17	101.81	0.1314	4.6	40.9%	92.34	0.0980	2.4	43.5%	**97.07**	**0.1147**	**3.5**	**42.2%**	
	I-17 - Van Buren St	69.67	0.1073	1.9	7.7%	78.15	0.1084	2.1	11.9%	**73.91**	**0.1078**	**2.0**	**9.8%**	
	Van Buren St - Southern Ave	56.05	0.0911	4.5	3.0%	54.38	0.0892	3.0	1.5%	**55.22**	**0.0901**	**3.8**	**2.2%**	
	Southern Ave - Ray Rd	64.68	0.1304	4.4	2.0%	68.16	0.0989	3.1	6.0%	**66.42**	**0.1146**	**3.8**	**4.0%**	
	Ray Rd - Wild Horse Pass Blvd	50.49	0.0792	3.5	2.6%	48.41	0.0779	3.4	0.0%	**49.45**	**0.0786**	**3.5**	**1.3%**	

Segment Data		Eastbound/Northbound				Westbound/Southbound				Bidirectional Average				
Route	Segment	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Notes
I-17	I-10 - 19th Ave	63.92	0.1273	6.9	24.4%	66.66	0.0992	11.8	52.5%	**65.29**	**0.1133**	**9.3**	**38.4%**	
	19th Ave - AZ Canal Trail	45.56	0.1105	0.0	1.0%	46.11	0.0800	0.1	0.0%	**45.83**	**0.0952**	**0.1**	**0.5%**	
	AZ Canal Trail - SR-101L	80.82	0.1459	12.1	83.8%	76.20	0.1044	11.7	77.9%	**78.51**	**0.1251**	**11.9**	**80.9%**	
	SR-101L – SR-74	54.74	0.1612	4.9	7.4%	62.40	0.1146	5.3	7.4%	**58.57**	**0.1379**	**5.1**	**7.4%**	
SR-51	I-10 - Shea Blvd	77.76	0.0943	6.2	20.8%	77.80	0.0894	10.0	43.0%	**77.78**	**0.0918**	**8.1**	**31.9%**	
	Shea Blvd – SR-101L	68.47	0.0845	3.8	3.0%	63.29	0.0807	4.0	0.0%	**65.88**	**0.0826**	**3.9**	**1.5%**	
SR-101L	I-10 - Union Hills Dr	61.27	0.0701	5.8	0.7%	64.42	0.0674	9.1	13.4%	**62.84**	**0.0688**	**7.4**	**7.0%**	
	Union Hills Dr - I-17	71.38	0.0900	11.5	69.4%	68.37	0.0863	5.1	4.0%	**69.88**	**0.0882**	**8.3**	**36.7%**	
	I-17 - Pima Rd	63.34	0.0775	9.9	48.5%	64.16	0.0806	16.7	59.8%	**63.75**	**0.0790**	**13.3**	**54.2%**	Currently being resurfaced
	Pima Rd - Shea Blvd	71.63	0.0817	4.7	2.3%	66.91	0.0941	8.0	9.1%	**69.27**	**0.0879**	**6.3**	**5.7%**	
	Shea Blvd – SR-202L (Red Mtn)	48.79	0.0638	4.5	10.0%	49.32	0.0643	3.5	3.0%	**49.05**	**0.0641**	**4.0**	**6.5%**	
	SR-202L (Red Mtn) – US-60	71.32	0.0959	10.8	56.4%	87.41	0.1026	9.3	63.2%	**79.37**	**0.0992**	**10.1**	**59.8%**	
	US-60 - SR-202L (Santan)	52.49	0.0713	7.9	29.9%	57.31	0.0741	8.0	30.4%	**54.90**	**0.0727**	**7.9**	**30.1%**	Currently being resurfaced

Segment Data		Eastbound/Northbound				Westbound/Southbound				Bidirectional Average				
Route	Segment	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Seg. Avg. IRI	Seg. Avg. Rut	Seg. Avg. Crack	% Failure	Notes
SR-143	Van Buren St - Belleview St	111.40	0.1155	6.2	41.7%	108.52	0.1377	6.1	41.7%	**109.96**	**0.1266**	**6.1**	**41.7%**	
SR-202L	SR-51 - Van Buren St	91.43	0.0899	2.5	4.8%	97.33	0.0994	8.3	40.0%	**94.38**	**0.0946**	**5.4**	**22.4%**	
	Van Buren St - McClintock Dr	102.19	0.0942	4.4	10.5%	91.42	0.0828	9.9	27.9%	**96.80**	**0.0885**	**7.2**	**19.2%**	
	McClintock Dr - Alma School Rd	54.61	0.0696	3.2	0.0%	54.14	0.0738	3.5	0.0%	**54.37**	**0.0717**	**3.3**	**0.0%**	
	Alma School Rd - University Dr	52.28	0.0672	5.5	10.7%	55.45	0.0738	4.1	12.0%	**53.87**	**0.0705**	**4.8**	**11.4%**	
	University Dr - Southern Ave	53.93	0.0583	4.7	0.0%	46.81	0.0664	5.3	5.0%	**50.37**	**0.0624**	**5.0**	**2.5%**	
	Southern Ave - Gilbert Rd	59.11	0.1123	8.7	23.4%	57.95	0.0973	7.7	24.1%	**58.53**	**0.1048**	**8.2**	**23.8%**	
	Gilbert Rd - Cooper Rd	66.22	0.1060	6.8	0.0%	70.81	0.1382	6.2	0.0%	**68.52**	**0.1221**	**6.5**	**0.0%**	
	Cooper Rd - McClintock Dr	67.21	0.1144	7.3	14.0%	69.04	0.1118	7.5	12.3%	**68.13**	**0.1131**	**7.4**	**13.2%**	
	McClintock Dr - Kyrene Rd	68.23	0.1228	8.2	24.0%	74.59	0.1200	12.0	84.0%	**71.41**	**0.1214**	**10.1**	**54.0%**	
	Kyrene Rd - 48th St	65.60	0.0848	5.9	33.3%	80.50	0.0656	6.9	37.1%	**73.05**	**0.0752**	**6.4**	**35.2%**	

Segment Data		Eastbound/Northbound				Westbound/Southbound				Bidirectional Average				Notes
Route	**Segment**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	**Seg. Avg. IRI**	**Seg. Avg. Rut**	**Seg. Avg. Crack**	**% Failure**	
SR-303L	I-10 - Bell Rd	46.42	0.0890	5.3	3.9%	57.59	0.0892	5.5	10.7%	**52.01**	**0.0891**	**5.4**	**7.3%**	
	Bell Rd - Happy Valley Pkwy	45.83	0.0720	2.8	0.0%	41.18	0.0723	2.7	0.0%	**43.50**	**0.0722**	**2.7**	**0.0%**	
US-60	I-10 - SR-101L	64.99	0.0967	13.7	95.8%	76.19	0.0797	1.0	0.0%	**70.59**	**0.0882**	**7.3**	**47.9%**	
	SR-101L - Power Rd	68.31	0.0896	11.8	79.0%	74.98	0.1039	2.7	8.4%	**71.65**	**0.0967**	**7.3**	**43.7%**	
	Power Rd - Crismon Rd	59.32	0.0887	10.7	57.5%	66.37	0.1161	5.0	10.0%	**62.84**	**0.1024**	**7.9**	**33.8%**	
	Crismon Rd - Maricopa Co Line	71.41	0.0672	8.5	25.0%	57.88	0.1162	6.7	5.0%	**64.65**	**0.0917**	**7.6**	**15.0%**	

APPENDIX C – Systemwide Life-Cycle Cost Analysis

Table C-1 shows summary statistics for the regional freeway system that currently has rubberized asphalt overlays broken down by freeway type (State Route, US Highway, or Interstate).

Table C-1 – Rubberized Asphalt Statistics				
	State Routes	**US Highways**	**Interstates**	**Total**
Total Length (miles)	176.4	22.3	69.5	**268.2**
Total Lane Miles	1,753.6	287.4	748.4	**2,789.4**
Total Shoulder Lane Miles	673.8	85.2	269.8	**1,028.8**

Table C-2 provides a summary of the life-cycle cost analysis performed for this task. The life-cycle costs are developed for the years 2026-2050, as funding through December 31, 2025 has already been programmed with Proposition 400 funding. Any funding for new pavement rehabilitation and reconstruction is assumed would likely come from an extension of Proposition 400, beginning in 2026.

As shown in *Table C-2*, there are several additional costs assumed for the concrete treatments related to converting from rubberized asphalt overlays to a concrete treatment. The bridge joint replacement cost is a one-time cost incurred at the time the first concrete treatment is applied; the remaining costs (concrete joint sealing, spot regrooving, partial and full depth concrete repairs) are assumed costs for systemwide spot repairs to the concrete based on a previous analysis performed by ADOT.

It is assumed that none of these additional costs would be incurred if rubberized asphalt overlays are continued as the preferred quiet pavement treatment because the existing bridges are built to accommodate the rubberized asphalt overlays and the rubberized asphalt overlay minimizes the impacts of damage to the underlying concrete surface.

Table C-3 includes the full life-cycle cost analysis utilized for the total treatment cost for this analysis (the concrete spot repair costs and the one-time bridge joint replacement cost were applied after this analysis). Parameters and assumptions for the life-cycle cost analysis are as follows:

- Life-cycle cost years: 2026-2050
- Unit Costs: (including removals, materials, traffic control, pavement markings, CE, contingency, ICAP)
    - Rubberized Asphalt Overlay: $116,000/lane mile
    - Diamond Grind Treatment: $123,000/lane mile
    - Whisper Grind Treatment: $150,000/lane mile
    - Skidabrader Treatment: $90,000/lane mile
- Treatment Service Life:
    - Rubberized Asphalt Overlay: 10 years
    - Concrete Treatments: 15 years

Table C-2 – Life-Cycle Cost Summary				
	Rubberized Asphalt	**Diamond Grind**	**Whisper Grind**	**Skidabrader**
Rubberized Asphalt Treatment Costs				
State Route Lanes	$799,170,000	$548,826,000	$669,300,000	$401,580,000
US Highway Lanes	$129,665,000	$91,660,000	$111,780,000	$67,068,000
Interstate Lanes	$311,066,000	$204,598,000	$249,510,000	$149,706,000
Cost for Pavement Treatment (2020-2050)	**$1,239,901,000**	**$845,084,000**	**$1,030,590,000**	**$618,354,000**
Concrete Costs Incurred for Converting from Rubberized Asphalt to Concrete Treatment				
Bridge Joint Replacement[1]	$0	$8,500,000	$8,500,000	$8,500,000
Concrete Joint Sealing[2]	$0	$5,200,000	$5,200,000	$5,200,000
Spot Regrooving[3]	$0	$7,400,000	$7,400,000	$7,400,000
Partial Depth Concrete Repairs[4]	$0	$24,400,000	$24,400,000	$24,400,000
Full Depth Concrete Repairs[5]	$0	$22,200,000	$22,200,000	$22,200,000
Cost for Switching to Concrete Treatment Total	**$0**	**$67,700,000**	**$67,700,000**	**$67,700,000**
Total Life-Cycle Cost (2026-2050)	**$1,239,901,000**	**$912,794,000**	**$1,098,290,000**	**$686,054,000**

1. Bridge joint replacement assumptions: 500 bridges on the system; 2 joints per bridge; average bridge width of 68'; bridge joint replacement cost of $125 per foot; one-time cost to address bridge transitions that currently have a grade difference to account for rubberized asphalt overlay.

2. Concrete joint sealing assumptions: $5,800,000 for systemwide joint sealing (2018-2045) from previous ADOT analysis; $214,814.81 annual cost for join sealing; applied for 2026-2050 and rounded to nearest $100,000.

3. Spot regrooving assumptions: $8,300,000 for systemwide spot regrooving (2018-2045) from previous ADOT analysis; $307,407.41 annual cost for spot regrooving; applied for 2026-2050 and rounded to nearest $100,000.

4. Partial depth concrete repairs assumptions: $27,500,000 for systemwide partial depth concrete repairs (2018-2045) from previous ADOT analysis; $1,018,518.52 annual cost for partial depth concrete repairs; applied for 2026-2050 and rounded to nearest $100,000.

5. Full depth concrete repairs assumptions: $25,000,000 for systemwide full depth concrete repairs (2018-2045) from previous ADOT analysis; $925,925.93 annual cost for full depth concrete repairs; applied for 2026-2050 and rounded to the nearest $100,000.

Table C-3 – Life-Cycle Cost Detailed Calculations

Route	From	To	Year Rubberized Asphalt Applied for Life-Cycle Analysis	Lanes	Aux Lanes	Length (mi)	Lane Miles	Shldrs	Shldr Lane Miles	Rubber-ized Asphalt Age (in 2026)	2026-2050 Rubber-ized Asphalt Overlays Req'd	Single Rubber-ized Asphalt Overlay Cost ($M)	2026-2050 Rubber-ized Asphalt Cost ($M)	2026-2050 Concrete Treat-ments Req'd	Single Diamond Grind Cost ($M)	2026-2050 Diamond Grind Cost ($M)	Single Whisper Grind Cost ($M)	2026-2050 Whisper Grind Cost ($M)	Single Skid. Cost ($M)	2026-2050 Skid. Cost ($M)
SR-51	SR-101L	Shea Blvd	2004	8	2	6.5	65	2	13	22	3	9.05	27.14	2	9.59	19.19	11.70	23.40	7.02	14.04
	Shea Blvd	I-10	2004	10	0	9.4	94	2	18.8	22	3	13.08	39.25	2	13.87	27.75	16.92	33.84	10.15	20.30
SR-101L	I-10	Union Hills Dr	2005	8	2	14.5	145	4	58	21	3	23.55	70.64	2	24.97	49.94	30.45	60.90	18.27	36.54
	Union Hills Dr	I-17	2004	8	2	7.4	74	4	29.6	22	3	12.02	36.05	2	12.74	25.49	15.54	31.08	9.32	18.65
	I-17	Pima Road	2020	10	2	13.5	162	4	54	6	2	25.06	50.11	1	26.57	26.57	32.40	32.40	19.44	19.44
	Pima Road	Shea Blvd	2025	8	2	4.4	44	4	17.6	1	2	7.15	14.29	1	7.58	7.58	9.24	9.24	5.54	5.54
	Shea Blvd	SR-202L (Red Mtn)	2016	10	2	10	120	4	40	10	3	18.56	55.68	2	19.68	39.36	24.00	48.00	14.40	28.80
	SR-202L	US-60	2005	12	1	4	52	4	16	21	3	7.89	23.66	2	8.36	16.73	10.20	20.40	6.12	12.24
	US-60	SR-202L (Santan)	2020	10	2	7.2	86.4	4	28.8	6	2	13.36	26.73	1	14.17	14.17	17.28	17.28	10.37	10.37
SR-143	Van Buren St	Belleview St	2004	4	0	0.7	2.8	4	2.8	22	3	0.65	1.95	2	0.69	1.38	0.84	1.68	0.50	1.01
SR-202L	I-10	Van Buren St	2004	10	0	4.2	42	4	16.8	22	3	6.82	20.46	2	7.23	14.46	8.82	17.64	5.29	10.58
	Van Buren St	McClintock Dr	2005	11	1	4.5	54	4	18	21	3	8.35	25.06	2	8.86	17.71	10.80	21.60	6.48	12.96
	McClintock Dr	Alma School Rd	2010	10	2	3.3	39.6	4	13.2	16	3	6.12	18.37	2	6.49	12.99	7.92	15.84	4.75	9.50
	Alma School Rd	Southern Ave	2016	8	2	18	180	4	72	10	3	29.23	87.70	2	31.00	61.99	37.80	75.60	22.68	45.36
	Southern Ave	Cooper Rd	2006	6	2	15.5	124	4	62	20	3	21.58	64.73	2	22.88	45.76	27.90	55.80	16.74	33.48
	Cooper Rd	McClintock Dr	2005	8	2	5.7	57	4	22.8	21	3	9.26	27.77	2	9.82	19.63	11.97	23.94	7.18	14.36
	McClintock Dr	Kyrene Rd	2003	8	2	2.5	25	4	10	23	3	4.06	12.18	2	4.31	8.61	5.25	10.50	3.15	6.30
	Kyrene Rd	48th St	2008	8	0	2.3	18.4	4	9.2	18	3	3.20	9.60	2	3.39	6.79	4.14	8.28	2.48	4.97
	48th St	I-10	2019	8	2	22	220	4	88	7	3	35.73	107.18	2	37.88	75.77	46.20	92.40	27.72	55.44
SR-303L	I-10	Bell Rd	2014	6	2	11.8	94.4	4	47.2	12	3	16.43	49.28	2	17.42	34.83	21.24	42.48	12.74	25.49
	Bell Rd	Happy Valley Rd	2016	6	0	9	54	4	36	10	3	10.44	31.32	2	11.07	22.14	13.50	27.00	8.10	16.20
US-60	I-10	SR-101L	2010	10	2	4.4	52.8	4	17.6	16	3	8.17	24.50	2	8.66	17.32	10.56	21.12	6.34	12.67
	SR-101L	Power Rd	2007	12	2	11.9	166.6	4	47.6	19	3	24.85	74.54	2	26.35	52.69	32.13	64.26	19.28	38.56
	Power Rd	Crismon Rd	2007	12	2	4	56	4	16	19	3	8.35	25.06	2	8.86	17.71	10.80	21.60	6.48	12.96
	Crismon Rd	County Line	2008	4	2	2	12	2	4	18	3	1.86	5.57	2	1.97	3.94	2.40	4.80	1.44	2.88

Route	From	To	Year Rubberized Asphalt Applied for Life-Cycle Analysis	Lanes	Aux Lanes	Length (mi)	Lane Miles	Shldrs	Shldr Lane Miles	Rubber-ized Asphalt Age (in 2026)	2026-2050 Rubber-ized Asphalt Overlays Req'd	Single Rubber-ized Asphalt Overlay Cost ($M)	2026-2050 Rubber-ized Asphalt Cost ($M)	2026-2050 Concrete Treat-ments Req'd	Single Diamond Grind Cost ($M)	2026-2050 Diamond Grind Cost ($M)	Single Whisper Grind Cost ($M)	2026-2050 Whisper Grind Cost ($M)	Single Skid. Cost ($M)	2026-2050 Skid. Cost ($M)
I-10	Verrado Way	191st St	2011	6	0	2	12	4	8	15	3	2.32	6.96	2	2.46	4.92	3.00	6.00	1.80	3.60
	191st St	Sarival Ave	2016	8	2	4.2	42	4	16.8	10	3	6.82	20.46	2	7.23	14.46	8.82	17.64	5.29	10.58
	Sarival Ave	Dysart Rd	2011	10	2	3.3	39.6	4	13.2	15	3	6.12	18.37	2	6.49	12.99	7.92	15.84	4.75	9.50
	Dysart Rd	75th Ave	2021	10	2	3.6	43.2	4	14.4	5	2	6.68	13.36	1	7.08	7.08	8.64	8.64	5.18	5.18
	75th Ave	43rd Ave	2019	12	2	4	56	4	16	7	3	8.35	25.06	2	8.86	17.71	10.80	21.60	6.48	12.96
	43rd Ave	I-17	2021	12	2	2.6	36.4	4	10.4	5	2	5.43	10.86	1	5.76	5.76	7.02	7.02	4.21	4.21
	I-17	Van Buren St	2024	10	2	4.8	57.6	4	19.2	2	2	8.91	17.82	1	9.45	9.45	11.52	11.52	6.91	6.91
	Van Buren St	Southern Ave	2024	12	2	7	98	4	28	2	2	14.62	29.23	1	15.50	15.50	18.90	18.90	11.34	11.34
	Southern Ave	Ray Rd	2024	8	2	4.7	47	4	18.8	2	2	7.63	15.27	1	8.09	8.09	9.87	9.87	5.92	5.92
	Ray Rd	Wild Horse Pass Blvd	2008	8	2	2.8	28	4	11.2	18	3	4.55	13.64	2	4.82	9.64	5.88	11.76	3.53	7.06
I-17	SR-74	SR-101L	2010	8	2	9.4	94	4	37.6	16	3	15.27	45.80	2	16.19	32.37	19.74	39.48	11.84	23.69
	SR-101L	Dunlap Ave	2005	8	2	6.8	68	4	27.2	21	3	11.04	33.13	2	11.71	23.42	14.28	28.56	8.57	17.14
	Dunlap Ave	19th Ave	2017	8	2	10.2	102	4	40.8	9	3	16.56	49.69	2	17.56	35.13	21.42	42.84	12.85	25.70
	19th Ave	I-10	2008	6	0	4.1	24.6	2	8.2	18	3	3.80	11.41	2	4.03	8.07	4.92	9.84	2.95	5.90
		Systemwide Totals:	-	-	-	**268**	**2,789**	-	**1,029**	-	-	**442.91**	**1,239.90**	-	**469.64**	**845.08**	**572.73**	**1,030.6**	**343.64**	**618.35**