ADOT

JUNE 2019

Transportation Asset Management Plan

Arizona Department of Transportation

Transportation Asset Management Plan

June 28, 2019

Respectfully Submitted:

____

John S. Halikowski, Director
Arizona Department of Transportation

Prepared by:

____

Thor Anderson, Asset Manager
Arizona Department of Transportation

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
AIC	Alternative Investment Choices
AMS	Arizona Management System
ARFC	Asphalt Rubber Friction Course
BrM	AASHTOWare Bridge Management Software
CGR	Compound Growth Rate
COG	Council of Governments
CPI	Consumer Price Index
DOT	Department of Transportation
dTIMS	Deighton Total Infrastructure Management System
ECD	Enforcement and Compliance Division
FAHP	Federal Aid Highway Program
FAST	Fixing America's Surface Transportation
FHWA	Federal Highway Administration
FMS	Financial Management Services
FY	Fiscal Year
HPMS	Highway Performance Monitoring System
HURF	Highway User Revenue Fund
IRI	International Roughness Index
LCP	Life Cycle Planning
MAP-21	Moving Ahead for Progress in the 21st Century Act of 2012
MPD	Multimodal Planning Division
NBI	National Bridge Inventory
MPO	Metropolitan Planning Organization
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis System
NBIS	National Bridge Inspection Program
NHS	National Highway System
OA	Obligation Authority
P2P Link	Planning to Programming Process
PCI	Pavement Condition Index
PMS	Pavement Management System
PTF	Public Transportation Fund
RARF	Regional Area Road Fund
RIC	Recommended Investment Choice
SHS	State Highway System
SOGR	State of Good Repair
STBGP	Surface Transportation Block Grant Program
STIP	Statewide Transportation Improvement Program
TAM	Transportation Asset Management
TAMP	Transportation Asset Management Plan
TIP	Transportation Improvement Program
TSMO	Transportation System Management & Operations
U.S.	United States
USGS	United States Geological Survey
WIM	Weigh-in-motion
WMYA	What Moves You Arizona
YOE	Year of Expenditure

Contents

Section 4: Life Cycle Planning 26

Section 5: Risk Management 48

Section 6: Financial Plan 64

Tables

Figures

Section 1
Executive Summary

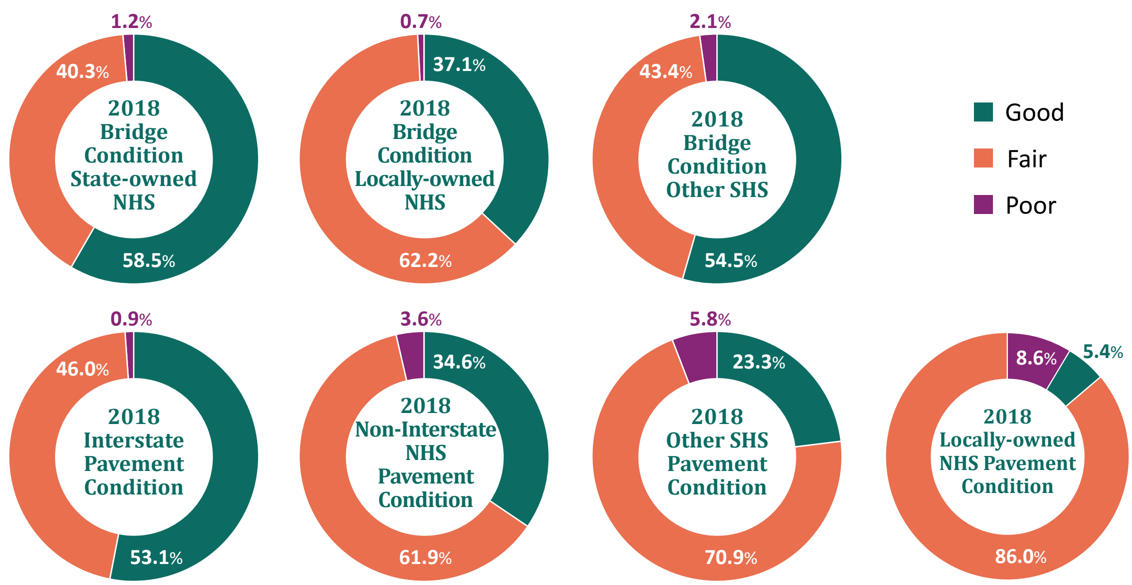
This risk-based Transportation Asset Management Plan (TAMP) documents strategic and systematic processes for maintaining and improving physical assets at the Arizona Department of Transportation (ADOT). The objective is to develop data-oriented investment strategies to achieve the desired state of good repair over the life cycle of assets. These asset management practices help ensure that ADOT can provide dependable and efficient operation of its transportation network to improve Arizona's economic competitiveness and quality of life. Moreover, the safety and welfare of the traveling public depend on the successful management of transportation assets.

1.1 Asset Portfolio & Performance Targets

ADOT is responsible for the operation and management of the State Highway System which has a historical cost of more than $22 billion. This TAMP contains the two most significant physical asset classes managed by ADOT: pavement and bridges. Reporting on the National Highway System is mandated by the Federal requirements in 23 CFR 515; however, ADOT is also including non-NHS pavement and bridges on the State Highway System. The total system covered in this TAMP includes 22,960 lane miles and 5,102 bridges, which make up a total of 46,791,031 square feet of bridge deck area.

Since the early 1980's, ADOT has been using management tools and processes to manage, maintain and preserve Arizona's highway network. The consistent use of these asset management processes has contributed to maintaining asset performance. To support the management of inventory and condition data, ADOT has been implementing the American Association of State Highway and Transportation Officials Bridge Management Software (AASHTOWare BrM 6.0) for bridges and the Deighton Total Infrastructure Management System (dTIMS) as its pavement management system. Currently, ADOT's assets are mostly in Good and Fair condition.

2018 Bridge and Pavement Condition



As required by the Federal performance management rules for bridges and pavements (23 CFR Part 490.105), ADOT has formally adopted performance targets based on current and historical condition. These targets consist of six pavement and bridge measures of Good and poor condition.

Two- and Four-Year Asset Performance Targets (Established in 2018)

Performance Target	2-Year Target	4-Year Target
Percent of NHS bridges classified as in good condition	52%	52%
Percent of NHS bridges classified as in poor condition	4%	4%
Percent of Interstate pavements in good condition	-	48%
Percent of Interstate pavements in poor condition	-	2%
Percent of Non-Interstate NHS pavements in good condition	31%	31%
Percent of Non-Interstate NHS pavements in poor condition	6%	6%

1.2 Life Cycle Planning (LCP)

In the past, like most other Departments of Transportation (DOTs), ADOT adopted asset management practices based on a reactive approach. This approach focused on expensive rehabilitation and reconstruction of assets in the worst condition, rather than applying preservation treatments before assets reached a significant deteriorated condition, an approach which can extend the asset life at lower costs. In recent years, ADOT has begun to develop technology and business processes that more rigorously forecast future preservation and rehabilitation needs, as a means of optimizing investments. These systematic processes help identify ADOT's best alternatives to preserve or improve asset condition. ADOT's LCP approach for both pavements and bridges models different combinations of work types, such as maintenance, preservation, rehabilitation and reconstruction, over the whole life of network assets to compare the effectiveness of different investment strategies on asset performance. In addition, this analysis facilitates asset management planning as it estimates network funding needs and identifies the impacts to the asset class if a sufficient investment is not made.

1.3 Risk Management

Risk management strengthens asset management by identifying strategies to respond to risks that can impact ADOT's ability to meet the asset management objectives. ADOT has developed a risk register that contains the risks, ratings, risk owner and high-level summary of the recommended risk mitigations. Although this TAMP focuses on bridges and pavements, the risk analysis included consideration of other assets on the NHS and SHS. There are 27 total risks identified in this TAMP, of which 16 are high and very high priority. Mitigations are recommended for these high priority risks which include extreme weather, inadequate funding, staff attrition, and flooding damage, among others.

Per Federal regulations, ADOT also identified four locations where pavement and bridge assets have been repeatedly damaged by emergency events and conducted statewide evaluations to determine if there are reasonable alternatives.

1.4 Financial Planning

ADOT relies on Federal, state, regional, and local sources of revenue to finance highway investments. ADOT's primary funding sources include the Federal Aid Highway Program (FAHP), state Highway User Revenue Funds (HURF), regional funding primarily through county approved taxes for transportation purposes, and local government investments.

Primary policy direction established as part of the What Moves You Arizona (WMYA) 2040 Statewide Long Range Transportation Plan includes three programs: preservation, modernization, and expansion.

- **Preservation**. Spending to maintain pavements in good condition and maintain bridges in a state of good repair.
- **Modernization**. Non-capacity spending that improves safety and operations of the existing SHS through activities such as adding shoulders and implementing smart road technologies.
- **Expansion**. Improvements that add capacity to the SHS through new roads, adding lanes to existing highways and constructing new interchanges.

WMYA 2040 envisioned a shift in ADOT investments in highways from physical expansion of highways to preservation of existing assets. The 25-year revenue estimate in the plan indicates that $23 billion in constant dollars will be available for highway capital spending. This equates to an average annual revenue of $923 million, which was used as the available funding estimate for developing the Statewide and regional transportation investments.

WMYA 2040 recommended investing $326 million annually for bridge and pavement preservation, about 30% more than was allocated in the previous program (WMYA 2035). The additional funding was made available by phasing out expansion projects in greater Arizona, outside the Maricopa Association of Governments (MAG) and Pima Association of Governments (PAG) areas. The number of expansion projects in greater Arizona is decreasing on a year over year basis and will be phased out completely by the end of 2024.

1.5 Investment Strategies

Based on the expected funding available for managing pavements and bridges over the next 10 years, results of the LCP and consideration of risks, ADOT has identified investment strategies for preserving the performance of pavement and bridges to maintain a state of good repair. The selected investment strategies reflect an increased investment in preservation activities and a shift away from the worst-first approach used in the past, following recommendations established as part of the What Moves You Arizona (WMYA) 2040 Statewide Long-Range Transportation Plan.

1.5.1 Bridge Investment Strategy

ADOT considered two investment strategies for bridges, generated using the AASHTOWare BrM 6.0. Based on ADOT's definition of bridge state of good repair, the selected investment strategy results in no performance gap, however, there is expected to be a reduction in the percent of bridge deck area in good condition over the next ten years, mainly driven by the aging of many of the highway system's larger bridges.

Recommended Bridge Investment Strategy Summary

	Average Annual Investment ($M)	Projected % Good (Year 10)	Projected % Poor (Year 10)
NHS	59	23%	1%
SHS	82	23%	1%

1.5.2 Pavement Investment Strategy

ADOT selected a pavement investment strategy that reflects an increased investment in preservation beginning immediately and continuing over the duration of the 10-year period at an average annual funding level of $241 million. The strategy also reflects a continued investment in rehabilitation activities to address the deterioration expected on portions of the system, but minimal reliance on reconstruction. This investment strategy achieves the percent Good targets for each pavement class and does not exceed the percent Poor targets for all systems. At no time over the 10-year period is the Interstate pavement network expected to exceed the Federal minimum condition target of 5% Poor.

Recommended Pavement Investment Strategy Summary

	Class Category	Average Annual Investment ($M)	Projected % Good (Year 10)	Projected % Poor (Year 10)
NHS	Interstate	163.8	58%	<1%
	State-Maintained NHS		41%	3%
	Locally-Maintained NHS		34%	7%
Non - NHS	High-Volume	77.1	37%	4%
	Low-Volume		30%	36%

1.6 Continuous Improvement

Based on the current state of transportation asset management (TAM) at ADOT and the gaps identified in TAM practice during the development of this document, the following opportunities for improvement have been identified for consideration:

- Complete implementation of dTIMS pavement management system and conduct life cycle planning to generate more detailed projections;
- Implement the work plan identified in Section 4.3 for AASHTOWare Bridge Management System (BrM 6.0) process enhancements and in Section 4.4 for dTIMS pavement management system enhancements.
- Update the TAMP to reflect any changes to investment strategies and/or performance targets using the updated management systems
- Develop guidance to ensure that pavement and bridge preservation treatments are used effectively, as outlined in the TAMP

Section 2
Introduction

Moving Ahead for Progress in the 21st Century Act of 2012 (MAP-21), identified the following national transportation system goal areas (Figure 1):

Figure 1 — National Transportation System Goal Areas

Increase Safety	Infrastructure Conditions	Congestion Reduction	System Reliability	Freight Movement & Economic Vitality	Environmental Sustainability
Reduce traffic fatalities and serious injuries on all public roads	*Maintain the National Highway System in a state of good repair*	*Reduce congestion on the National Highway System*	*Improve the efficiency of the surface transportation system*	*Improve the national freight network, strengthen rural access to national/international markets and support economic development*	*Enhance performance of the transportation system while protecting and enhancing the natural environment*

Transportation asset management regulations associated with the Infrastructure Conditions goal require the development of a risk-based Transportation Asset Management Plan (TAMP) covering National Highway System (NHS) bridges and pavements.

The regulations were implemented in two stages:

- Development of an initial TAMP, due April 30, 2018, that included some plan elements plus a description of the processes and methodologies.
- Development of a final TAMP, due June 30, 2019, containing all required plan elements.

> *As defined in MAP-21: Asset management is a strategic and systematic process of operating, maintaining and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation and replacement actions that will achieve and sustain a desired state of good repair over the life-cycle of the assets at minimum practicable cost.*

This final TAMP presents the following required content for Arizona Department of Transportation (ADOT):

- Asset management objectives (**Section 2.1**);
- A summary description of the condition of NHS pavements and bridges, regardless of ownership (**Section 3**);
- Asset management performance measures and ADOT targets for asset condition (**Section 3.4**);
- Performance gap analysis (**Section 7**);
- Risk management analysis, including an evaluation of facilities repeatedly damaged by emergency events (**Section 5**);
- Network life cycle planning (**Section 4**);
- A financial plan (**Section 6**); and
- Investment strategies (**Section 7**).

While Federal regulations only require the inclusion of pavement and bridge assets on the National Highway System (NHS), this TAMP includes all State Highway System (SHS) bridge and pavement assets, representative of the approach ADOT follows to manage all assets comprehensively. It covers a ten-year planning horizon. In future years, TAMP updates may include other assets, such as pump stations, tunnels and signs. To effectively include other assets in the TAMP, it will be necessary to develop comprehensive inventory and condition data sets for these assets, which may take several years.

> *The NHS, developed by the U.S. Department of Transportation in conjunction with local, state and metropolitan planning organizations, includes the Interstate highway system and other roads important to the nation's economy, defense and mobility. Most of the NHS is a part of the SHS. In Arizona, a small portion of NHS routes are owned and operated by local public agencies. Unless otherwise specified, a reference to NHS in this report will include both the state and local portions.*

ADOT is responsible for the construction, operation, management and maintenance of the State Highway System (SHS) which comprises more than 21,000 lane miles and has a historical cost of more than $22 billion. The dependable and efficient operation of this transportation network is vital to Arizona's economic competitiveness and quality of life. Moreover, the safety and welfare of the travelling public depends on the successful management of the transportation assets on the SHS (**Figure 2**) and the NHS (**Figure 3**).

Most of ADOT's bridge and pavement infrastructure will reach the end of their design life cycle over the next 10 years. With proper preservation treatments, the life of this infrastructure can be extended. However, as Arizona's highway system ages, the resources needed to maintain it will increase. This makes the identification and implementation of strategies that preserve existing assets while controlling costs essential to sustaining a balanced, fiscally sound state highway program.

Like most other state Departments of Transportation (DOTs), ADOT has historically used a common asset management strategy that ranks assets by condition and prioritizes repair, rehabilitation and reconstruction primarily on a "worst first" basis. This reactive approach tends to focus on expensive rehabilitation and reconstruction projects, rather than applying preservation treatments before deterioration is noticeable, which can extend asset lifespans at lower costs. Recently, DOTs are determining that a strategy that optimizes the application of maintenance, preservation, rehabilitation and replacement throughout an asset's life cycle is a more cost-effective way to manage highway infrastructure. Managing assets throughout their life cycle with an increased emphasis on preservation treatments is a proactive approach, requiring a long-term perspective and significant planning. It is becoming a standard practice for DOTs to address this planning need with the development of a Transportation Asset Management Plan (TAMP). ADOT has adopted this strategy of asset life cycle management and this TAMP and the investment strategies identified show a significant investment in preservation treatments to slow the rate of deterioration and preserve the condition of the transportation system as much as possible.

Figure 2 — State Highway System

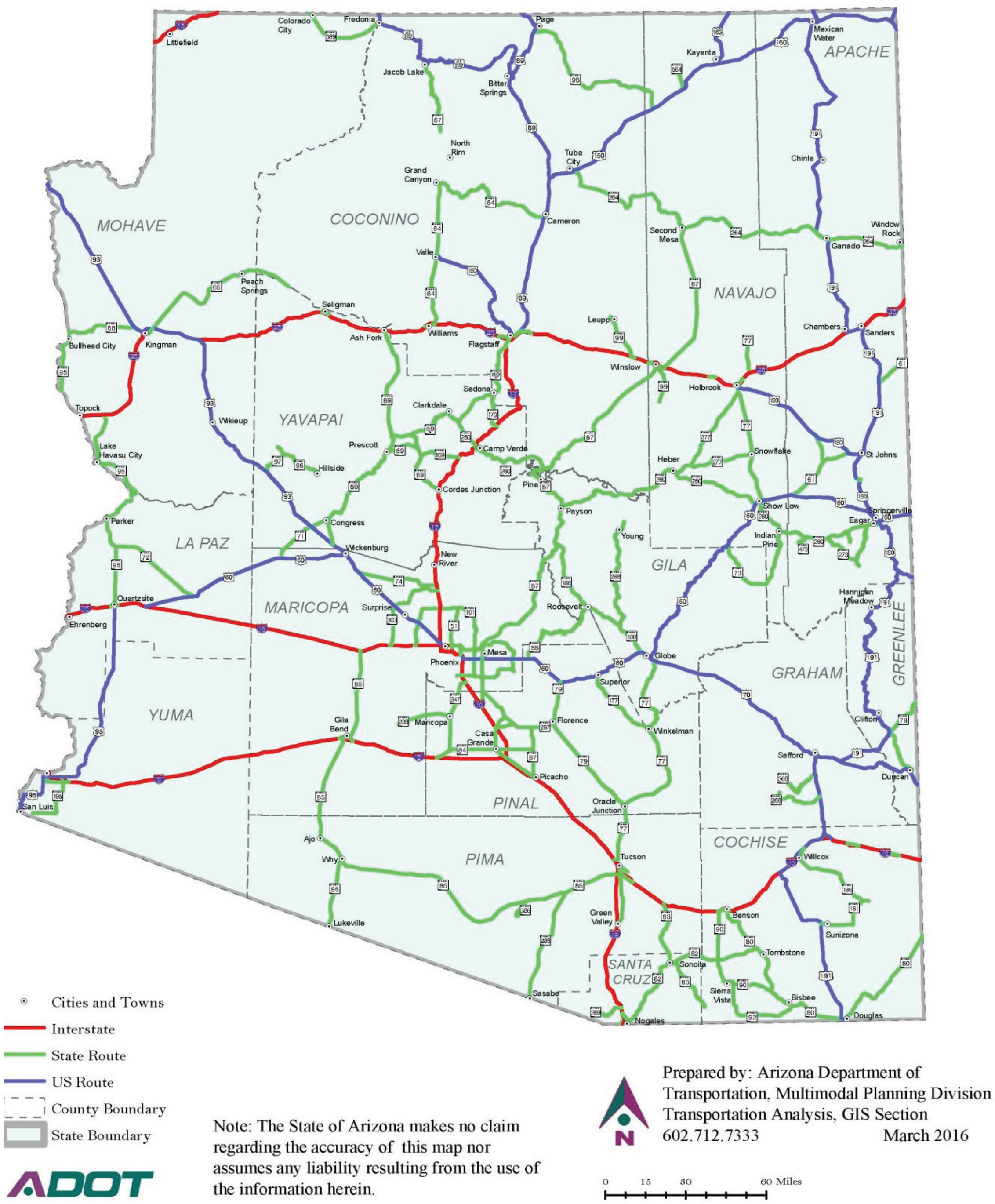
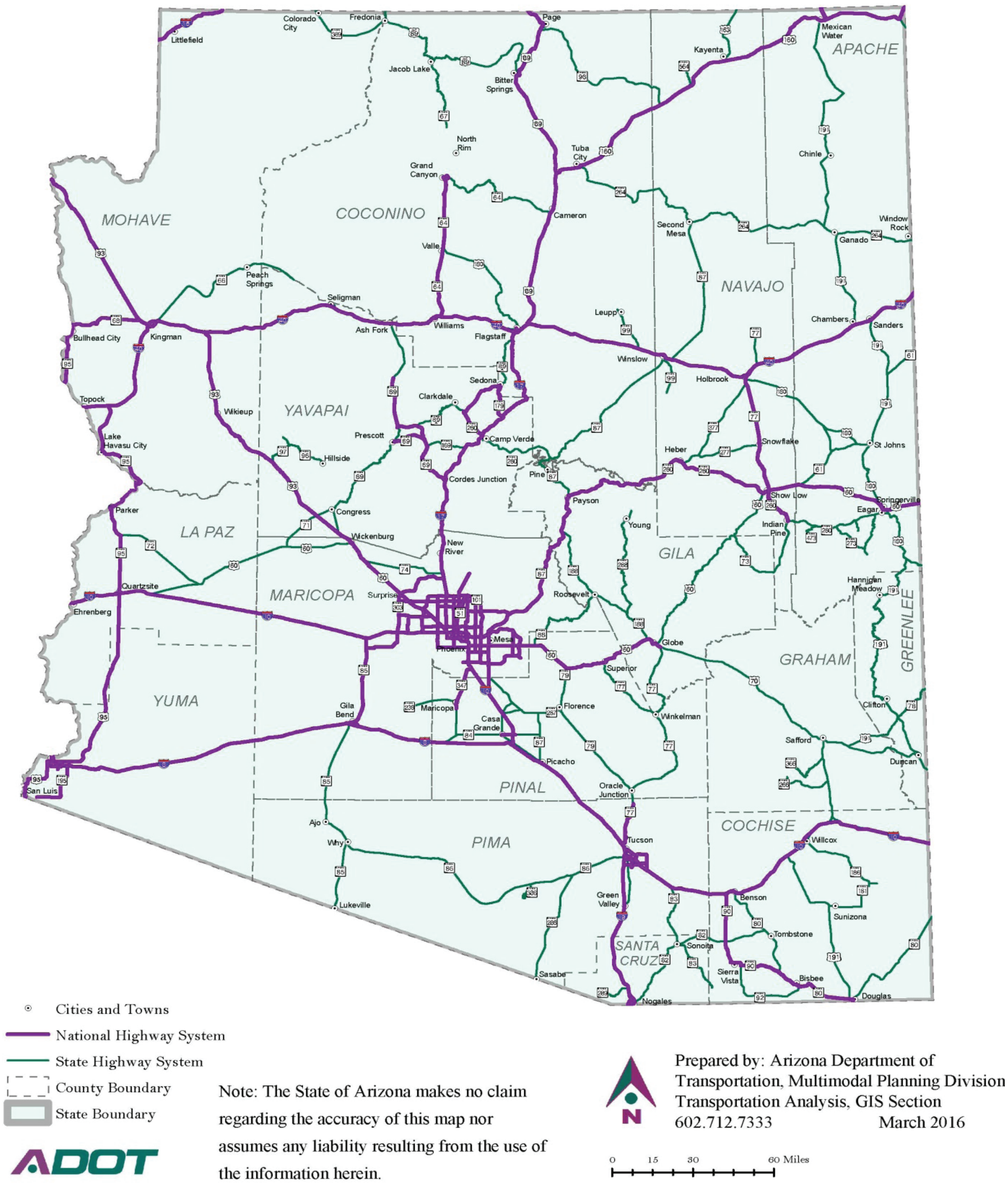


Figure 3 — National Highway System



2.1 Asset Management Objectives

This TAMP is a comprehensive blueprint for extending the life of Arizona's highway system while maintaining reliable performance and minimizing long-term costs. This approach aligns well with ADOT's mission and vision (Figure 4).

Figure 4 — ADOT's Mission, Vision and True North

Mission	Vision	True North
CONNECTING ARIZONA	MOVING ARIZONA	PEOPLE-CENTRIC
Everyone. Every day. Everywhere.	*Become the safest, most reliable transportation system in the nation*	*Making transportation personal*

ADOT's objectives for transportation asset management are to:

- Develop a collaborative process that integrates the efforts of data managers, engineers, maintenance personnel, planners, financial specialists and executives in the management of ADOT's transportation assets.
- Improve ADOT's asset management business practices to support safe, efficient, reliable, resilient and sustainable highway infrastructure.
- Maintain the fundamental function and reliability of the as-built highway system (state of good repair).
- Factor risk into asset management planning.
- Manage transportation assets throughout their life cycle in the most cost-effective manner, with a focus on low cost maintenance and preservation treatments.
- Maintain the reliability of ADOT's bridges and pavements by identifying gaps in asset condition performance and investment strategies that could narrow or close those gaps.
- Communicate financial needs for maintaining the highway system in a state of good repair to ADOT's stakeholders.
- Improve transparency, accountability and decision-making in the management of ADOT's transportation infrastructure.
- Incorporate Arizona Management System (AMS) principles in ADOT's management of transportation assets. See Section 2.5.

2.2 Asset Management Oversight and Operating Structure

Developing and implementing transportation asset management within ADOT is a major undertaking and requires involvement of staff throughout the agency. Table 1 lists the committees responsible for implementation of this effort. Numerous specialists from ADOT's planning, data management, risk management, finance and other areas also participated in the development of this TAMP.

Table 1 — Asset Management Committees

Committee	Purpose	Membership
Asset Management Steering Committee	Sets the general direction for the TAMP, including ensuring that transportation asset management is integrated across the appropriate levels of the organization; approving policies, programs, processes and performance targets necessary for the implementation of transportation asset management; approval of the final TAMP.	• ADOT Director, Chair • FHWA Arizona Division Administrator • Deputy Director for Transportation • Deputy Director for Policy • Deputy Director for Business Operations • Chief Financial Officer • Secretary (Transportation Asset Manager and/or Assistant Director for Multimodal Planning Division)
Asset Management Working Group	Supports the implementation of the TAMP, including developing performance measures and state targets to be reviewed for approval by the steering committee; identifying and prioritizing risks to ADOT's transportation infrastructure; recommending changes to policies, procedures and processes to improve transportation asset management at ADOT; ensuring different groups and sections within ADOT work together to accomplish the development and implementation of the TAMP; review the draft TAMP.	• Transportation Asset Manager, Facilitator • FHWA Arizona – Division Representative • Assistant Director for Transportation Systems Management and Operations Division • Assistant Director for Infrastructure Delivery and Operations Division • Assistant Director for Multimodal Planning Division • Assistant Director for Communication • Deputy State Engineer – Operations • Deputy State Engineer – Design • Federal Aid Administrator – Financial Management Services • Chief Economist – Financial Management Services • Budget Manager – Financial Management Services • Debt Management and Compliance Administrator – Financial Management Service
Asset Management Technical Teams	Support the development of performance targets and the TAMP, including compiling and analyzing data to support the development of performance targets; use bridge and pavement management systems to perform gap and life cycle analysis that cover a range of funding scenarios; identifying investment strategies for the cost-effective management of these assets; assist with the development of the TAMP.	**Bridge Technical Team** • Transportation Asset Manager, Facilitator • State Bridge Engineer • FHWA Arizona-Division Representative • Assistant State Bridge Engineer – Design • Assistant State Bridge Engineer – Operations • Bridge Management Engineer • Financial Management Services Staff • Multimodal Planning Staff **Pavement Technical Team** • Transportation Asset Manager, Facilitator • State Maintenance Engineer • FHWA Arizona-Division Representative • Pavement Management Engineer • Pavement Design Engineer • Financial Management Services Staff • Multimodal Planning Staff

2.3 Asset Management and the Planning Process

Over the last decade, long-range transportation planning in Arizona evolved from an emphasis on individual projects to a focus on overall system performance. ADOT's long-range transportation plan, *What Moves You Arizona 2040* (WMYA 2040), uses performance measures and data-driven analysis to evaluate different investment scenarios to recommend the most realistic allocation of resources for the expansion, modernization and preservation of Arizona's highway system. To channel these high-level investment choices into the selection of specific projects, ADOT adopted a new planning-to-programming (P2P) process known as P2P Link. P2P Link combines performance criteria with professional judgement to select and prioritize projects for ADOT's Five-Year Transportation Facilities Construction Program within the Statewide Transportation Improvement Program (STIP).

The ability to implement performance-based planning is being enhanced by improvements in the collection of asset condition data combined with the availability of sophisticated analytical tools that model future asset performance. These developments together make it feasible to evaluate a range of asset management planning scenarios to identify one that best meets agency goals at a minimum practical cost. This TAMP provides the analytical basis to support both high level resource allocation decisions in long-range transportation plan updates, and the development of asset specific investment strategies to guide project selection under the P2P Link process. Over time, the incorporation of TAMP findings in ADOT's performance-based planning process is expected to improve accountability and decision-making by:

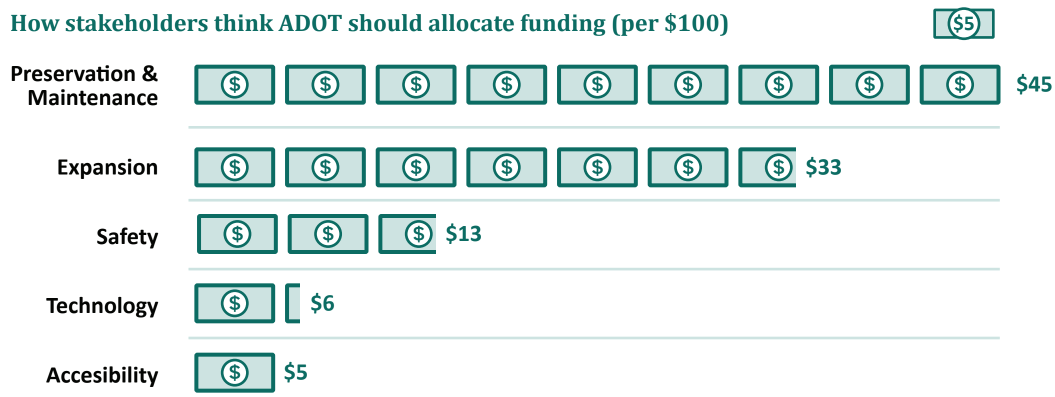
- Providing feedback on progress towards performance targets; and
- Increasing transparency by showing how data and analysis informs funding recommendations.

Local governments who own and operate NHS bridges and pavements are also involved in asset management planning through participation in the development of Metropolitan Transportation Plans and Transportation Improvement Programs (TIPs), and/or by working directly with ADOT to incorporate asset improvement projects in the STIP. ADOT has worked with Arizona's Metropolitan Planning Organizations (MPOs) and Councils of Government (COGs) to develop a planning agreement that identifies how data collection, performance targets and asset management planning will be coordinated and how each party will contribute. The planning agreements are available in **Appendix A**.

2.4 Public Support for Highway Preservation

During the development of WMYA 2040, ADOT worked collaboratively with Arizona's MPOs and COGs to implement an extensive public involvement process that included outreach sessions, workshops, a plan website and the use of social media. Outreach efforts included an interactive online survey that asked for input on future investment priorities, funding allocation strategies and preferred trade-offs. As illustrated in **Figure 5**, Arizona's citizens place the highest priority on preserving and maintaining the existing highway system (WMYA 2040, 2018). It should be noted that outside of Phoenix and Tucson areas, citizens identified safety as the second highest priority after preservation and maintenance.

Figure 5 — Investment Priority Survey Results



SOURCE: WMYA 2040 (2018)

2.5 Arizona Management System (AMS)

AMS is a people-centered, results-driven approach to continuously improving state government with a focus on customer service, transparency and accountability to the citizens of Arizona. AMS intends to streamline state government operations and is based on principles of Lean management; the essence of the Lean principles is to foster respect for people and to continuously improve by understanding customer needs, identifying problems, improving processes and measuring results. AMS intends for the state government to operate at the speed of business through structured problem solving and data-driven decision making.

Arizona's TAMP aligns well with this performance-based approach – this document outlines the resources needed to preserve both bridge and pavement assets, supporting the achievement of agency performance targets. Moreover, the TAMP will be the focal point of an on-going effort to make ADOT's transportation infrastructure more reliable while using state resources in the most cost effective manner. The TAMP is a living document that will be updated at least every four years. Initial and on-going improvements to ADOT's Asset Management program will utilize AMS principles, practices and tools (https://ams.az.gov).

Section 3
Asset Inventory & Condition

3.1 Introduction

To effectively manage assets at a network level, it is necessary to have an accurate account of bridge and pavement inventory and condition data. These data are the foundation of this TAMP, and support ADOT's asset management processes.

The Arizona TAMP focuses on the two most significant physical asset classes managed by ADOT: pavement and bridges. Reporting on the National Highway System (NHS) is mandated by the Federal requirements in 23 CFR 515, however ADOT is also including non-NHS pavement and bridges on the State Highway System (SHS).

The ADOT NHS consists of 3,335 bridges with a total deck area of 34,467,021 square feet and 13,899 lane-miles of pavement. Non-NHS assets included in this TAMP are 1,767 additional bridges with a deck area of 12,324,010 square feet and 9,061 lane miles of pavement. ADOT technical experts regularly perform condition inspections of state-owned and, in some cases, locally-owned roadway assets. This section summarizes the asset inventory and results of the condition inspections for bridges and pavements.

3.2 Bridge Assets

3.2.1 Bridge Inventory Summary

ADOT owns and operates all the bridges and culverts on the SHS, and most of these structures on the NHS. Local governments also own and operate bridges and culverts on the NHS. Table 2 shows the breakdown of the bridge inventory included in this TAMP by bridge category, and Table 3 shows a breakdown of the locally-owned NHS bridges. The Arizona SHS includes the state-owned NHS bridges and other SHS bridges for a total of 4,803 bridges. In addition to the 299 locally-owned bridges, this TAMP covers a total of 5,102 bridges.

Table 2 — Arizona Highway System Bridges*

Bridge Owner	Number of Bridges	Bridge Deck Area (square feet) †
State-owned NHS Bridges	3,036	31,426,851
Locally-owned NHS Bridges	299	3,040,170
Total NHS Bridges	**3,335**	**34,467,021**
Total Other SHS Bridges	**1,767**	**12,324,010**
Total Bridges Covered in the TAMP	**5,102**	**46,791,031**

** Includes culverts. Culverts that have an opening that is less than 20 feet in span parallel to the roadway are not included in this tally or in the TAMP.*

† System-wide bridge condition ratings are typically reported by deck area since this metric accounts for the variance in bridge size throughout the state.

SOURCE: ADOT 2018

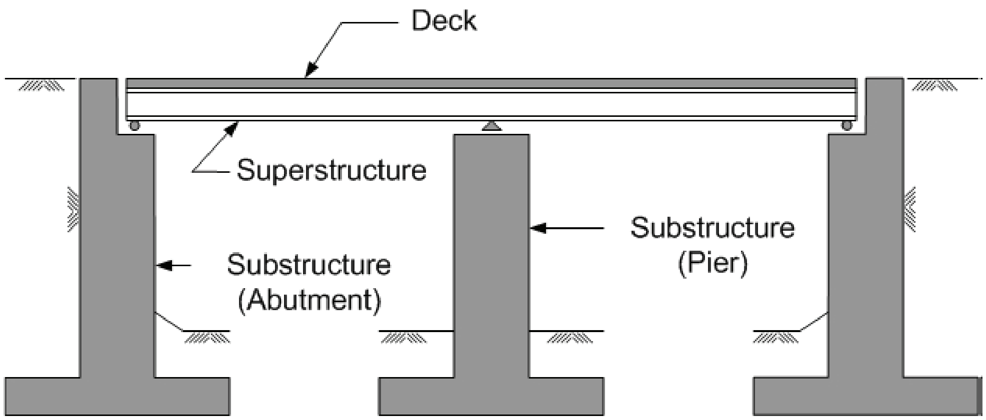
Table 3 — Locally-Owned NHS Bridges

Bridge Owner	Number of Bridges	Bridge Deck Area (square feet)
Fountain Hills	1	3,300
Gilbert	2	63,106
Glendale	7	130,242
Goodyear	2	9,368
Marana	9	31,868
Maricopa Co	5	44,434
Mesa	13	164,635
Paradise Valley	1	2,176
Peoria	2	66,876
Phoenix	105	1,354,068
Pima Co	42	424,461
Sahuarita	2	3,912
Scottsdale	16	93,008
Sierra Vista	4	13,872
Surprise	2	6,186
Tempe	2	9,400
Tucson	82	551,480
Yavapai Co	1	25,226
Yuma City	1	42,552
Total	**299**	**3,040,170**

3.2.2 Bridge Data Management

ADOT inspects most of Arizona's publicly owned bridges, including all the bridges on the SHS and most the bridges owned or operated by local governments. Routine bridge inspections occur every two years and assess the condition of a bridge's primary components: deck, superstructure and substructure (Figure 6).

Figure 6 — Schematic Bridge Elevation View



SOURCE: U.S. DEPARTMENT OF TRANSPORTATION 2012; FHWA PUBLICATION NO. NHI 12-049

Culverts that are greater than 20 feet in length parallel to the roadway are considered bridge structures and are inspected every four years with a few exceptions. Culverts in Arizona are typically either a reinforced concrete box structure that supports the pavement or steel or concrete pipes (Figures 7 & 8).

Figure 7 — Box Culvert

Figure 8 — Pipe Culverts

All bridge and culvert inspections are performed in accordance with ADOT's bridge inspection guidelines, which comply with the National Bridge Inspection Standards (NBIS). ADOT's bridge inspection guidelines are referenced in Appendix A. These guidelines, along with bridge inspector training for ADOT staff and consultants, provide consistent inspections which result in accurate, reliable data.

One local government agency performs its own bridge inspections: Maricopa County DOT. ADOT performs bridge inspections for all other jurisdictions including the City of Phoenix Street Transportation Department. Appendix A references an intergovernmental agreement between the State of Arizona and Maricopa County and the City of Phoenix outlining bridge inspection standards, protocols and coordination. For an agency to perform their own bridge inspections, they must demonstrate compliance with the NBIS, and submit quarterly progress reports and an annual electronic National Bridge Inventory (NBI) record to the ADOT Bridge Inspection Program Manager. Jointly-owned border bridges with the City of Needles (California) and the states of California and Nevada are inspected by Caltrans or the Nevada Department of Transportation under intergovernmental agreements with the State of Arizona.

To help manage the inventory and inspection data, the department has been implementing and configuring the AASHTOWare Bridge Management software release 6.0, published by the American Association of State Highway and Transportation Officials (AASHTO). ADOT will continue to develop models to support life-cycle planning, risk analysis, and investment planning to comply with 23 CFR 515.17. The department has also developed in-depth spreadsheets to predict future preservation projects with NBI data as a backup to AASHTOWare Bridge Management.

3.2.3 Bridge Condition Summary

The NBI component rating system is used to assess bridge general condition for deck, superstructure and substructure. The culvert condition rating is based on the same scale, but rather than a component rating, there is one rating for the entire culvert. This rating system features a scale from 0 to 9. Each structure is assigned a good, fair or poor designation (Figure 9) based on the lowest scoring component.

Figure 9 — NBI Bridge Rating Scale

9 8 7	6 5	4 3 2 1 0
GOOD	**FAIR**	**POOR**
All bridge components rated good.	*The lowest rated bridge component is fair.*	*One of the bridge components is rated poor.*

Generally, these categories are defined as follows:

- **Good.** Primary structural components exhibit a range from no problems to some minor deterioration.
- **Fair.** Primary structural components are sound, but may have deficiencies such as minor concrete deterioration (cracking, spalling, scaling) or scour (erosion around piers or abutments caused by flowing water). Bridges in Fair condition are often considered for preservation or maintenance to prolong their functional life.
- **Poor.** Advanced deterioration, scour or seriously affected primary structural components (Figures 10 to 12). A poor condition bridge is sometimes described as “structurally deficient”. Bridges in poor condition need repair, maintenance and monitoring, and may be programmed for rehabilitation or replacement. The poor condition label does not necessarily mean that a bridge is unsafe. Bridges that are considered unsafe are closed until they can be repaired or replaced.

Figure 10 — Cracking and Spalling on a Bridge Deck

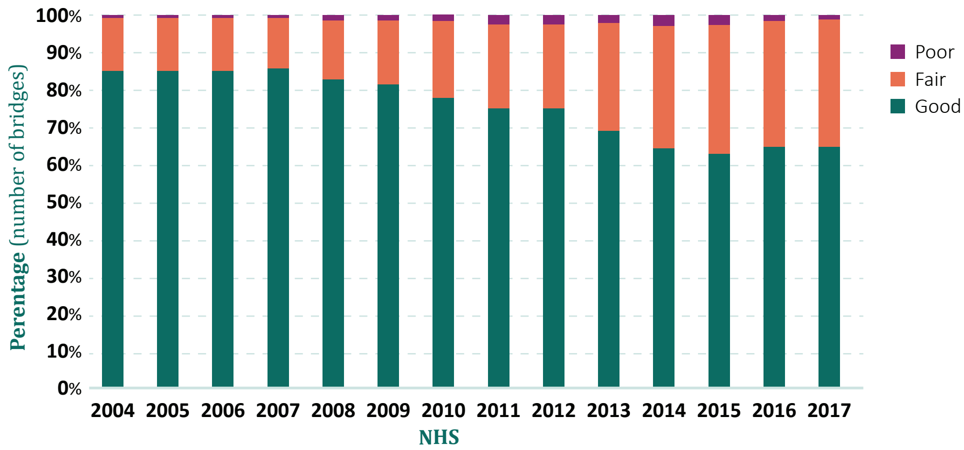
Figure 11 — Scour at a Bridge Pier

Figure 12 — Scaling on a Bridge Deck

ADOT has been collecting more detailed element-level data from bridge inspections since 2014. Examples of bridge elements are railing, deck wearing surface, deck slab, expansion joint, bearing, column, and abutment. The element-level inspection data support engineering decision making such as preservation treatment selection, and the forecasting of deterioration and life cycle costs.

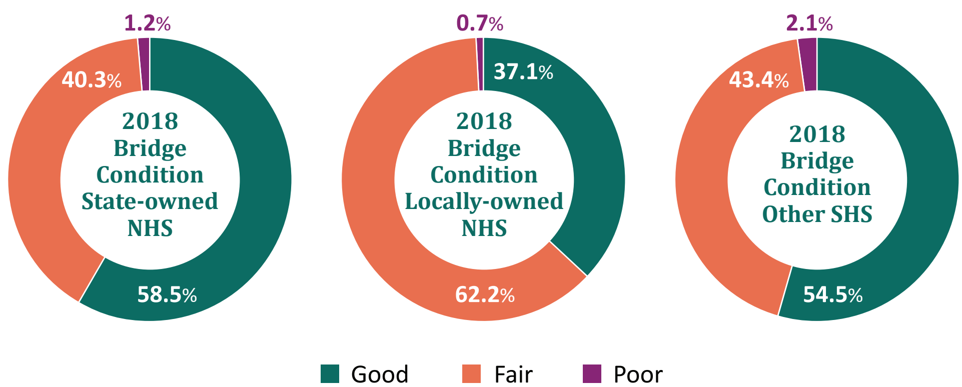
From 2008 to 2013, aging bridges steadily deteriorated (Figure 13). The most noticeable change was the percentage of bridges that worsened from good to fair condition, indicating insufficient spending on preservation. This downward trend stabilized over the past few years due to increased spending on bridges, particularly on rehabilitation and reconstruction. The number of poor and fair condition bridges has decreased during the period from 2015 through 2017.

Figure 13 — NHS Bridge Condition



Currently, most bridges on the Arizona SHS and NHS are in good condition. In fact, Arizona ranks in the top 10 in the nation for having the fewest poor condition bridges. This is because most bridges haven't reached the end of design life and the temperate Arizona climate. Figure 14 shows bridge conditions based on deck area for the three bridge categories included in this TAMP: State-owned NHS, Locally-owned NHS bridges, and Other SHS bridges.

Figure 14 — 2018 Bridge Conditions



3.3 Pavement Assets

3.3.1 Pavement Inventory Summary

This TAMP covers 22,960 lane miles of pavement, owned and managed by ADOT and local agencies. The Arizona NHS represents about 60% (13,899 lane miles) of the SHS. ADOT maintains all the pavement on the SHS, which includes the State-owned NHS. Local governments own and maintain pavement on about 13% of the NHS. The estimated 2018 lane mile for paved roads is shown in Table 4 with the breakdown of the locally-owned portion shown in Table 5.

Table 4 — 2018 Lane Mile Breakdown for Paved Roads

Pavement Asset Category	Through Lanes	Total Lane Miles*
Interstate (NHS)	5,176	5,405
State-owned, Non-interstate NHS	6,102	6,653
Locally-owned NHS	1,651	1,841
Total NHS Pavement	**12,929**	**13,899**
Total Other SHS Pavement	**7,736**	**9,061**
Total Pavement Covered in the TAMP	**20,665**	**22,960**

** Includes ramps, frontage, auxiliary and passing lanes.*

Table 5 — Locally-Owned NHS Pavement

Owner	Lane Miles
Buckeye	8.58
BIA	10.66
Carefree	0.55
Casa Grande	18.00
Cave Creek	3.13
Chandler	70.72
Douglas	0.35
El Mirage	3.70
Flagstaff	13.37
Fountain Hills	22.53
Glendale	76.92
Goodyear	27.33
Kingman	14.03
Litchfield Park	7.24
Maricopa County	78.66
Mesa	91.23
Nogales	0.25
Paradise Valley	15.79
Peoria	32.24
Phoenix	714.34
Pima County	17.86
Quartzsite	7.60
San Luis	7.92
Scottsdale	180.02
Somerton	12.36
Surprise	47.17
Tempe	84.18
Tucson	117.83
Tusayan	0.56
Williams	0.09
Yuma	73.02
Yuma County	82.68
Total	**1,840.91**

3.3.2 Pavement Data Management

Since the early 1980's, ADOT has been using pavement management tools to manage, maintain and preserve Arizona's highway network. ADOT is currently implementing the Deighton Total Infrastructure Management System (dTIMS) software as its pavement management system (PMS). This PMS utilizes asset inventory, asset condition, and life cycle strategies to predict future conditions and funding needs. At the network level, it also identifies the mix-of-fixes (combination of maintenance, rehabilitation, and reconstruction treatment) that can improve or sustain current pavement performance. ADOT will continue to calibrate and expand models within dTIMS to support life-cycle planning and investment planning in compliance with 23 CFR 515.17.

Historically, ADOT has performed annual pavement condition evaluations for state highways using in-house staff and equipment. ADOT used the Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) Field Manual (2014) methodology to collect pavement data. Local governments were expected to collect pavement condition data for the NHS routes they own. However, ADOT was unable to consistently obtain this data. To resolve this problem for 2017, ADOT hired a contractor to perform automated pavement data collection for the entire SHS and the locally-owned NHS. It is ADOT's intent to continue to collect pavement data for locally-owned NHS routes in future years. This data will be made available to local NHS asset owners for their use.

Fully automated pavement data collection is new to ADOT; however, the data is collected in accordance with HPMS methodology and is subject to a rigorous quality control review by ADOT's Pavement Management Section. A Data Quality Management Plan outlining pavement data collection and processing standards and procedures can be found in Appendix A.

ADOT's pavement asset inventory is comprehensive and reflects the different pavement types used across the state of Arizona, which includes asphalt, concrete and composite pavements. Each pavement type has a different life cycle and is managed differently. Descriptions are provided in Table 6.

Table 6 — Pavement Types

Pavement Type	Management
Asphalt	Constructed with petroleum-based bituminous materials. Commonly referred to as flexible pavement due to its low flexural strength. It can last 50+ years if properly maintained with periodic preservation and rehabilitation treatments. More than 90% of the pavement on the SHS is asphalt.
Concrete	Consists of Portland cement concrete. It may be constructed with joints to control cracking or without joints. Concrete pavement is either reinforced with steel or unreinforced (plain). Most of the concrete pavement on the SHS is jointed and unreinforced and called Jointed Plain Concrete Pavement. Concrete pavement is commonly referred to as rigid pavement due to its high flexural strength and can last 60+ years.
Composite	Consists of a foundation of concrete pavement overlaid with asphalt. On the SHS, the asphalt layer typically consists of a 1-inch-thick open-graded asphalt rubber friction course (ARFC). ADOT's open-graded asphalt is designed to have a high amount of air voids making the pavement water permeable, reducing splash and spray during wet weather. A high amount of air voids and the addition of ground tire rubber to the asphalt reduce road noise. An additional benefit of the ARFC layer is that it improves the smoothness of the pavement while maintaining an acceptable level of friction for stopping, resulting in better ride quality than a concrete surface. Typically, the overlay on a composite pavement lasts 10 to 15 years before it needs to be removed and replaced. About 7% of the pavement on the SHS is composite.

3.3.3 Pavement Condition Summary

Pavement condition data is complete for the four metrics required by the Federal Performance Management rules (PM2). Asphalt and composite pavement condition are evaluated using three metrics: International Roughness Index (IRI), percent cracking and rutting. Concrete pavement condition is evaluated using IRI, percent cracking and faulting metrics. A description of these metrics is presented in Table 7.

Table 7 — Pavement Condition Rating Metrics

Metric	Description	Example
IRI	International method for measuring the smoothness (or roughness) of pavements. This measure is strongly correlated to ride quality.	
Cracking	A fissure or discontinuity of the pavement surface not necessarily extending through the entire thickness of the pavement. Cracking is generally caused by repeated traffic loads or pavement shrinkage due to low temperatures.	
Rutting*	Surface depressions that run length-wise, usually in the wheel path, in an asphalt pavement. Rutting results from permanent deformation of any of the pavement layers or the subgrade. It is usually caused by the consolidation or lateral movement of the pavement materials due to heavy traffic loads.	
Faulting*	An elevation difference between two concrete slabs typically caused by poor load transfer between slabs, slab settlement or movement induced by erosion of material beneath the slab.	

** Photo taken from the 2016 HPMS Field Manual.*

If the condition for all three applicable metrics is good, then the pavement section is rated in good condition. If two or more metrics are rated poor, then the pavement section is rated in poor condition. All other rating combinations are fair condition. Table 8 shows the Federal thresholds for these metrics.

Table 8 — Federal Thresholds for Pavement Rating Metrics

Condition Rating	Good	Fair	Poor
IRI (inches/mile)	<95	95-170	>170
Cracking (percent)	<5	5-20 (asphalt)	>20 (asphalt)
		5-15 (jointed concrete)	>15 (jointed concrete)
		5-10 (continuously reinforced concrete)	>10 (continuously reinforced concrete)
Rutting (inches)	<0.20	0.20- 0.40	>0.40
Faulting (inches)	<0.10	0.10- 0.15	>0.15

ADOT makes a significant investment in maintaining interstate pavements. Historically, interstate pavements have been in good condition; although, the amount of fair condition interstate pavement has increased in recent years (Figure 15). Arizona's non-interstate NHS pavements receive less funding than the interstates and a higher percentage of these pavements have deteriorated to fair condition in recent years (Figure 16).

Figure 15 — Interstate NHS Pavement Condition

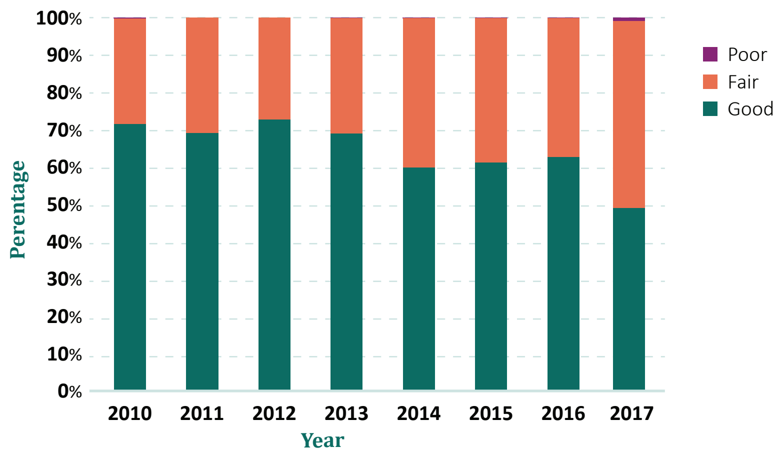


Figure 16 — Non-Interstate NHS Pavement Condition

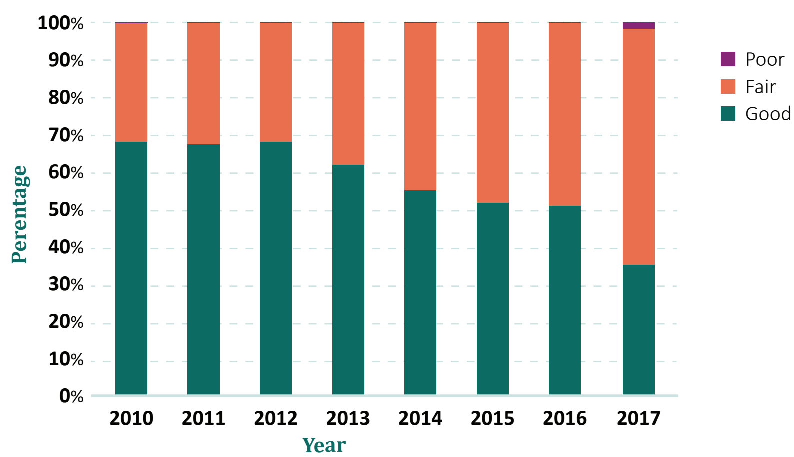
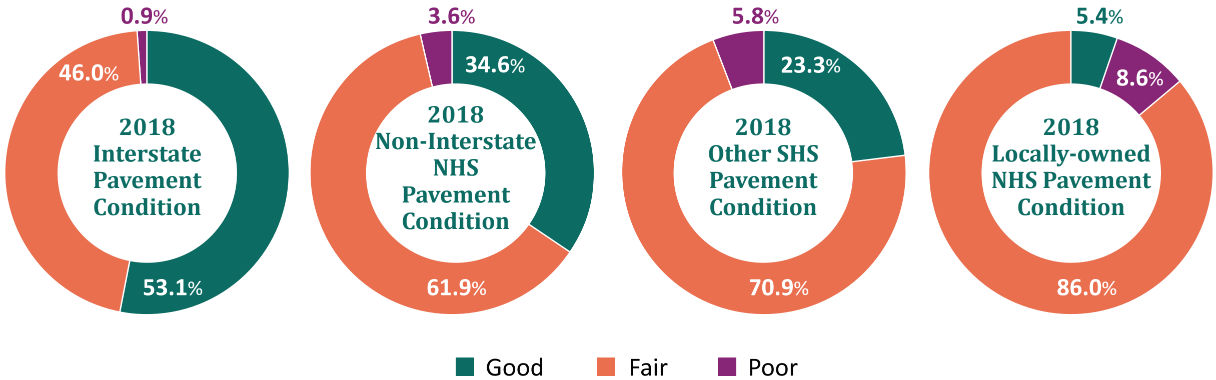


Figure 17 summarizes the 2018 condition of ADOT pavement using the Federal pavement performance thresholds. As shown, more than 50% of the Interstate pavements are classified as good, while majority of the Non-Interstate NHS and other SHS pavements are classified as fair. Approximately one percent (1%) of Interstate pavements, four percent (4%) of Non-Interstate NHS pavements, and six percent (6%) of Other SHS are classified as poor. Locally-owned NHS pavements are mostly in fair condition, with a larger percent (8.6%) in poor condition, as shown in the Figure.

Figure 17 — 2018 Pavement Conditions



ADOT makes a significant investment in maintaining Interstate pavements, which is reflected in the large percentage of pavements in good and fair condition. For the Interstate system, pavement condition has remained relatively stable for the past decade. However, many pavement segments in fair condition have the potential to fall into a poor condition in future years.

3.4 Asset Performance Measures & Targets

Performance measures and targets are the foundation on which state agencies do business under the Arizona Management System (AMS). The four key steps to implement AMS are:

1. **Identify what we do — the core processes that most impact our agency's missions and deliver customer value.**
2. **Set targets and standards for doing this work well.**
3. **Measure how we're doing relative to the targets and standards.**
4. **Where performance comes up short, use disciplined problem solving to implement counter measures to get our performance back on track.**

Following these steps defines the standard to be achieved, promotes transparency and accountability, and provides feedback for making improvements.

Transportation asset management is a core part of ADOT's mission and the performance-based TAMP is carried out in accordance with AMS principles. In asset management practice, performance measures, when linked with a target, can be used to measure progress and evaluate strategies for improvement. ADOT uses the performance measures and targets identified below to manage its bridges and pavements on the SHS to achieve a state of good repair. ADOT's definitions of a state of good repair for pavement and bridges are discussed in Section 3.4.2 and Section 3.4.3.

3.4.1 Federal Performance Measures – Bridges and Pavements

In this TAMP, performance measures and targets for managing bridges and pavements are the basis for assessment, analysis and planning. The Federal performance management rules for bridges and pavements (23 CFR Part 490.105) require state DOTs to establish targets for six pavement and bridge measures of good and poor condition. In addition, the rule sets the following minimum condition requirements:

- The percentage of Interstate pavement lane-miles in poor condition shall not exceed 5%.
- The percentage of the deck area of NHS bridges classified in poor condition shall not exceed 10%.

On May 20, 2018, ADOT formally adopted the performance targets for the bridge and pavement performance measures, based on current and historical condition, as presented in Table 9.

ADOT uses AASHTOWare Bridge Management software release 6.0 and is developing dTIMS pavement management system to predict long-term asset condition and future funding needs, to establish the ability to meet these targets.

Table 9 — ADOT Bridge and Pavement Performance Targets (established in 2018)

Performance Target	2-Year Target	4-Year Target
Percent of NHS bridges classified as in good condition	52%	52%
Percent of NHS bridges classified as in poor condition	4%	4%
Percent of Interstate pavements in good condition	-	48%
Percent of Interstate pavements in poor condition	-	2%
Percent of non-Interstate NHS pavements in good condition	31%	31%
Percent of non-Interstate NHS pavements in poor condition	6%	6%

3.4.2 State of Good Repair for Bridges

ADOT's work to maintain performance is driven by the requirement to maintain a State of Good Repair (SOGR). This concept is interpreted at both the bridge level and the network level.

- At the bridge level, a state of good repair means that the bridge is providing the desired level of service, and is in condition that is at least good enough to enable the most cost-effective maintenance and preservation.
- At the network level, a state of good repair means a performance level that can be sustained at minimal long term cost to the agency and to road users. This requires that maintenance and preservation are applied consistently and strategically; that risks are controlled by application of cost-effective mitigation actions; and that service disruptions or performance lapses are routinely corrected in a timely manner.

ADOT considers its National Highway System bridge and culvert inventory to be in excellent condition, at the current level of 56.6% Good and less than 1.1% Poor. As ADOT's bridge inventory ages, the overall system condition is expected to decline and ADOT's long-term performance targets take this into consideration. The aging bridge inventory includes quite a few very large bridges which have a disproportionately large effect on overall system condition. Given the objectives listed previously and the age of the bridge network ADOT believes that a state of good repair can be achieved with 10-year targets of 22% Good and 4% Poor (Table 10). As ADOT gains more experience in implementing the asset management strategies identified in the TAMP, including improvements in collecting element level data and enhancements to the bridge management system, these targets will be revised to better achieve the state of good repair objectives.

Table 10 — Desired Long-Term SOGR for Bridges

Bridge Class	Minimum % Good	Maximum % Poor
NHS	22	4
SHS	22	4

3.4.3 State of Good Repair for Pavements

The desired SOGR for pavements establishes a desirable level of service that can be sustained at a minimal long-term cost to the agency and road users. This reflects ADOT's strategy of increasing the use of routine maintenance and preservation activities to sustain pavement performance and reduce the long-term cost of managing the network.

Expected levels of funding are causing ADOT to make decisions about what level of service can be achieved and what portions of the network will experience increased deterioration. To allow ADOT to consider different LCP strategies and repair costs for each pavement class, the NHS was further broken out into three pavement classes (Interstates, Other NHS State-maintained routes, and Other NHS Locally-maintained routes) and the Non-NHS routes are subdivided into two pavement classes (high and low-volume routes). Table 11 presents the desired pavement SOGR for each pavement class.

Table 11 — Desired Long-Term SOGR for Pavements

Pavement Class	Minimum % Good	Maximum % Poor
Interstates	58	1
Other NHS – State Maintained	40	3
Other NHS – Locally Maintained	5	8
Non-NHS – High Volume	35	4
Non-NHS – Low Volume	30	36

Section 4
Life Cycle Planning

4.1 Introduction

Life Cycle Planning is a systematic process that identifies ADOT's best options to preserve or improve the condition of an entire asset class or across asset classes at the minimum practical cost. The LCP analysis models different combinations of work types, such as maintenance, preservation, rehabilitation and reconstruction, over the whole life of network assets to compare the effectiveness of different investment strategies on asset performance. In addition, this analysis facilitates asset management planning as it estimates network funding needs and identifies the impacts to the asset class if a sufficient investment is not made.

4.2 Life Cycle Planning in ADOT

Although Arizona's population and travel demand continue to grow, ADOT places highest priority on preservation of existing infrastructure. Maintenance and preservation are applied to assets that are in relatively good condition, because the strategic timing of this work is often the least expensive way to maintain service in the long term.

In past practice, the allocation of funds to these categories has been based on historic investment levels and professional judgment. As ADOT's assets have aged it has become increasingly apparent that a greater focus on preservation and increased funding levels will be needed to offset the effects of aging and deterioration.

ADOT has begun to develop technology and business processes that more rigorously forecast future preservation and rehabilitation needs, as a means of optimizing investments. While the Department continues to satisfy the immediate needs of its customers, it also is improving its ability to choose the scope and timing of preservation work to keep costs as low as possible over the long term. Since these methods differ between pavements and bridges, the two asset classes are discussed separately in the following sections.

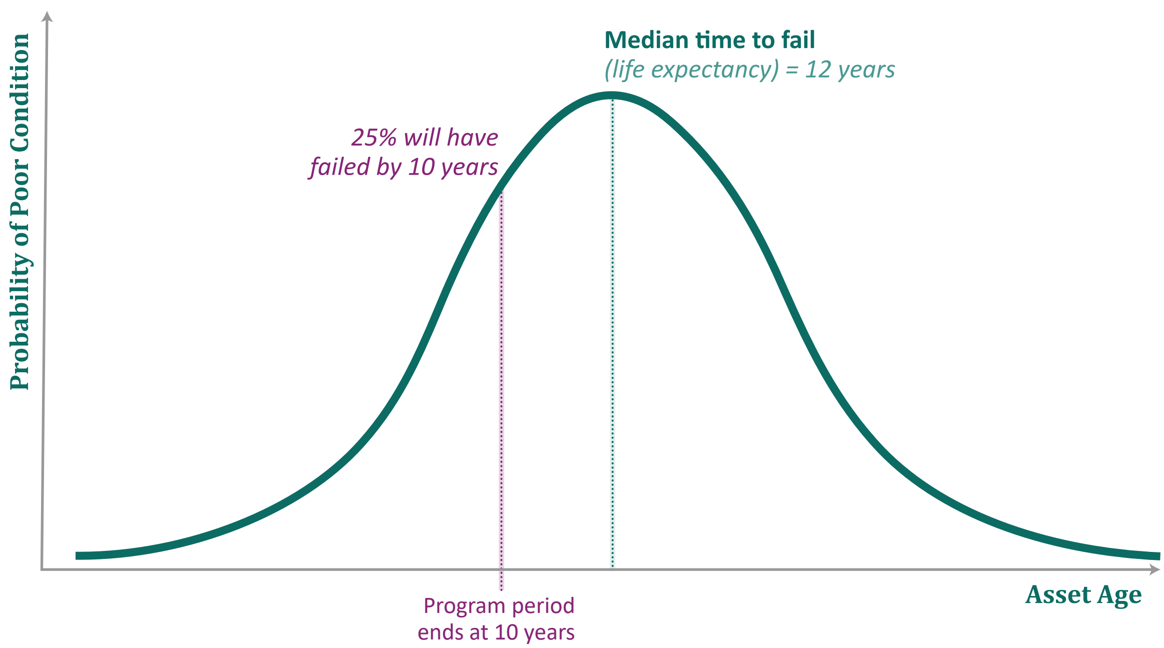
4.3 Bridge Life Cycle Planning

Arizona's bridges are under constant attack from deterioration and various hazards. Weather, aging, deicing chemicals, heavy trucks, and accidents contribute to the rate of decay. Most existing bridges in the state were designed for a 50-year life span, with some of the newest bridges designed for 75 years. However, bridges can be made to last much longer if appropriate steps are taken to preserve them.

The planning of preservation work is, in part, a scientific activity that depends on research about deterioration, risks, and costs. ADOT has taken steps to gather data and analyze it to enable the accurate forecasting of these factors. Forecasting always entails uncertainty about the future, so the models used for bridge life cycle planning are careful to consider uncertainty in planning.

Figure 18 shows an example of the effects of uncertainty. The graph shows the uncertainty in lifespan of a group of bridge decks that are currently in fair condition. Some of these decks may reach poor condition within just two years, while others might last two decades or longer. The median remaining life might be 12 years, yet a significant fraction will deteriorate to poor condition within 10 years. In a 10-year estimate of needs it would be important to make allowance for this “premature deterioration”, even though none have yet reached poor condition.

Figure 18 — Premature Deterioration as a Result of Uncertainty



Arizona’s varied climate makes it especially difficult to predict bridge asset lifespans due to large variations in temperature and precipitation. High elevation areas of the state frequently receive heavy snowfall and freeze and thaw cycles. More southerly and low elevation areas of the state receive scant rainfall and little to no freezing and thawing, however, the largest population centers are in the low elevation areas, bringing higher traffic and truck volumes.

Different parts of a bridge deteriorate at different rates. For example, expansion joints wear out quickly, while decks deteriorate at a moderate rate and piers often last a very long time. These different deterioration rates influence the timing of the work that must be done to overcome deterioration and keep bridges performing well. ADOT bridge inspectors monitor the conditions of all these bridge elements so they can detect the best opportunities for maintenance and preservation.

To keep track of its bridge condition data and to support its planning activities, ADOT has implemented the AASHTOWare Bridge Management Software (BrM). Some of the BrM capabilities ADOT will need for life cycle planning became available in the spring of 2019 and still require additional work to support full implementation. Nonetheless, ADOT is taking steps to allocate and train staff to take advantage of this tool as fully as possible.

4.3.1 Life Cycle Planning Process for Bridges

BrM was used to evaluate a worst-first and a preservation scenario using a multi-step process for conducting a LCP analysis as outlined below.

- **Form an LCP team.** A bridge task force was created to support the LCP analysis. The group included the TAMP manager, Assistant State Bridge Engineer, Operations Engineer and four senior Bridge Engineers who are responsible for long-term bridge planning and management.
- **Select the asset classes and networks to be analyzed.** The bridge inventory was evaluated in two categories: NHS-only routes, and SHS routes which includes the State-owned NHS.
- **Establish short- and long-term targets for each asset class.** In addition to the 2- and 4-year targets established for compliance with the Transportation Performance Management rules (23 USC 150), a desired State of Good Repair (SOGR) was established (see Section 3.4.2). The desired SOGR was used to compare the results of each LCP scenario to evaluate the level of service that could be achieved at the expected funding level.
- **Define LCP Strategies.** LCP strategies for each network were based on expected funding levels over a 10-year analysis period. The strategy development process involves the following steps:
  - *Identifying a range of treatments and establishing their costs. The treatments identified include routine maintenance, preservation, rehabilitation, and reconstruction. Since the routine maintenance treatments and costs had not yet been configured into BrM at ADOT, this treatment type was not included in the analysis. However, since maintenance activities typically do not improve condition levels, the absence of this information is not expected to affect the results of the analysis.*
  - *Establishing deterioration rates for bridge assets. Deterioration rates are from FHWA's deterioration model which is based on inspection data from 15 states, including Arizona. The models were used to predict changes in condition over the 10-year analysis period.*
  - *Distributing the available funding by work type for each scenario. The worst first scenario contained primarily rehabilitation and reconstruction with minimal preservation and no maintenance. The preservation scenario included maintenance, preservation, rehabilitation and reconstruction.*
- **Set LCP Scenario Inputs.** BrM used the asset inventory, 2018 bridge condition inspection results, expected deterioration rates, and treatment costs as the inputs. For the LCP analysis, expected funding levels over the next 10 years were also input into the analysis.
- **Develop LCP Scenarios.** Two scenarios were identified for analysis: a worst- first scenario representing ADOT's traditional bridge management practice, and a preservation scenario that included funding for both maintenance and preservation activities. The outputs generated show the resulting impact on system conditions over 10 years of spending in accordance with each scenario. The resulting outputs summarize the amount of work conducted in each category, the total amount spent, and the percent of the system that meets the desired SOGR so that ADOT could identify the most practicable strategy to minimize life cycle costs while striving to achieve desired bridge conditions.
- **Develop life cycle treatment recommendations for each network.** The LCP planning process resulted in the development of typical life cycle treatment recommendations that reflect ADOT's plans to increase investment in maintenance and preservation activities. The resulting treatment recommendations are presented in Section 4.3.5. As ADOT improves configuration of BrM, the treatment recommendations will be reviewed and modified to reflect the most recent inspection data and funding.

- **Provide input to financial planning.** The results of the LCP analysis were used to inform the investment choices in the long-range transportation plan and the 5-Year Transportation Facilities Construction Program section of the STIP.

Given that BrM is still under development there is a considerable amount of work that will need to be done to improve the reliability of the LCP analysis; these results are for high level planning purposes only. The work plan presented in Section 4.3.6 describes the intended steps towards improvement.

4.3.2 Drivers of Bridge Performance

Bridges influence the achievement of all Federal transportation system goals enumerated in 23 USC 150(b), which are also state goals. Specifically:

- **Safety.** Condition of bridge decks and expansion joints influences the probability of crashes. In addition, standards for bridge roadway width and railings influence the frequency and severity of crashes. The ability of bridges to avoid and/or resist certain natural or man-made hazards, such as flooding and over-height truck collisions, may have an impact on safety.
- **Condition.** Changes in condition resulting from normal deterioration influence the feasibility and cost of maintenance and preservation. Bridges that are allowed to deteriorate too far may require much more expensive rehabilitation or replacement. Therefore, condition is a primary driver of life cycle costs.
- **Mobility.** including congestion and reliability – The number of lanes and geometrics of bridges affect their ability to carry sufficient traffic at free-flowing legal speeds.
- **Freight Movement.** The demands of commerce rely on an increasing volume and weight of trucks. System performance is affected by increased rates of deterioration and by ADOT efforts to accommodate heavy truck traffic.
- **Environmental Sustainability.** Certain maintenance and preservation actions can have positive or negative impacts on the environment, depending on the methods used – in particular, painting and deck washing. Bridge inspection, especially of trusses and bearings, often requires cleaning (and accompanying environmental protection) to gain safe access and visibility. Traffic congestion on bridges contributes to air pollution due to slow moving and idling vehicles.
- **Project Delivery.** Work zone traffic control is increasingly important in deciding on the feasibility and timing of preservation work. ADOT strives to coordinate its bridge work with other needs on a corridor and with the work of other agencies, with the goal of delivering work quickly and with minimal disruption to the public.

Traffic growth is a causative factor for adverse changes in these aspects of performance. Particularly significant is the effect of heavier truck traffic statewide on deterioration rates, and the use of deicing chemicals to help maintain safe winter travel speeds at higher elevations receiving frequent snowfall. Performance is also affected by changes in functional requirements, changes in design standards, and by localized problems, such as the effect of reactive aggregates on the integrity of concrete materials.

These factors are closely associated with life cycle cost and risk. Preservation work is selected in a manner that tries to offset deterioration and reduce long-term costs, while also minimizing near-term inconvenience to the public. The risks associated with natural and man-made hazards are regularly assessed to consider the economic effect on road users when service is disrupted by bridge closures or restrictions. Effective planning of agency actions to protect and improve performance depends on several tools and concepts discussed in the following sections.

4.3.3 Forecasting Bridge Condition

ADOT has licensed release 6 of AASHTOWare Bridge Management (BrM) to support decision making related to the planning of work on existing structures. BrM can analyze condition at two levels of detail:

- **NBI components.** These are the traditional deck, superstructure, substructure, and culvert 0-9 rating system that ADOT has used since 1995.
- **AASHTO elements.** This is a more detailed system which describes each bridge as a collection of elements selected from a catalog of more than 100 types of bridge elements of varying functions and materials. Each element is rated on a scale of 1 (no defects) to 4 (severe defects). ADOT has been gathering condition data in this format since 2014.

Currently ADOT is using a bridge element deterioration model that was developed in 2016 for the National Bridge Investment Analysis System (NBIAS), a software tool used by the Federal Highway Administration (FHWA) for national planning of bridge needs as required for a periodic report to Congress. This model was based on bridge inspection data from 15 states, including Arizona. The model is stratified by climate, so Arizona is using the model for hot and dry states, which have relatively slow deterioration.

The NBIAS model was developed using bridge element inspection data gathered under the 1997 AASHTO Guide for Commonly-Recognized Structural Elements. Arizona data used in the model start with year 1999 inspections. After the model was developed in terms of the 1997 element definitions, it was converted to be compatible with the 2013 AASHTO Manual for Bridge Element Inspection, using a methodology developed by the Florida Department of Transportation.

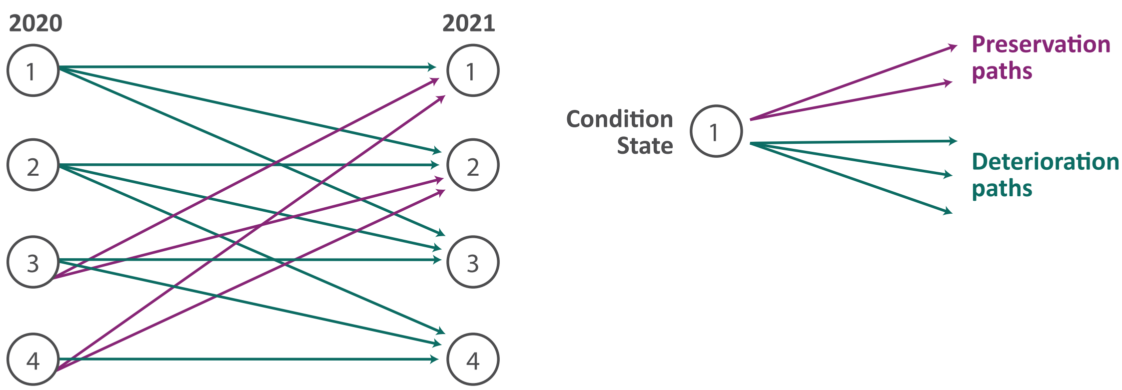
As discussed earlier, uncertainty is an essential part of any forecast of bridge conditions. As a result, BrM uses a probabilistic model to estimate the fraction of a population of elements in each condition state at any future point in time. The model has two parts, as depicted in Figure 19:

- Deterioration paths (green) estimate the downward movements among condition states from year to year, if no agency action is taken.
- Preservation paths (purple) estimate the upward movements among condition states when an agency conducts a preservation or rehabilitation action.

For convenience, deterioration models are typically expressed in terms of the median number of years to transition from each condition state to the next-worse state. The relative size of upward and downward movements determines the overall change in condition. If the upward and downward movements are balanced, then overall network condition remains unchanged.

Since the models quantify year-to-year changes in condition, they can be developed using a relatively small amount of data, two inspection cycles (four years) at a minimum. However, the models are more reliable if developed using a longer time series. Because of changes in AASHTO element inspection standards in 2013, ADOT has made plans to revise its deterioration models once it has 3 or 4 cycles of bridge inspections gathered under the newest manual. The work plan indicates this as one of the long-range implementation tasks.

Figure 19 — Changes in Condition Estimated by a Forecasting Model (1 is best condition state, and 4 is worst)



The Federal performance measures of percent Good and percent Poor are expressed in terms of NBI component ratings, but for most management purposes the element level is far superior. This is especially the case for planning of preservation activities, since they depend heavily on the condition of wearing surfaces, coatings, expansion joints, and other aspects of a bridge that are not quantified in the NBI component system, but are explicitly measured using elements.

For this reason, ADOT has found the NBI component level of analysis as supported in BrM to be unsuitable for life cycle planning. The element level of analysis is suitable and supported by BrM, but is not fully developed as of June 2019. The conversion of element condition forecasts into the Federal percent Good and percent Poor measures is not accurate, and the program lacks sufficient reporting capabilities for element-level condition forecasts and life cycle cost calculations. ADOT is cooperating with the software developer to help them further refine the necessary functionality.

Although the BrM software is still actively under development, ADOT has been able to use it in its current form to achieve some of its goals for life cycle planning, such as, scenario analysis and evaluating the feasibility of its long-range condition goals.

4.3.4 Treatments to Maintain and Improve Performance

ADOT maintains a Bridge Preservation Program manual to guide the planning of all types of work on existing bridges by both ADOT and local agencies. ADOT also uses the FHWA Bridge Preservation Guide to support this purpose. In terms of the FHWA treatment categories, the treatments documented in the ADOT manual can be classified per the following taxonomy.

- **Initial Construction.** Complete construction of a new bridge structure on a new alignment.
- **Replacement.** Removal of an existing bridge and construction of a replacement bridge to serve the same alignment as the removed bridge. Bridge replacement in Arizona has costs in the range of $300 to $450 per square foot. Since replacements are often necessitated by traffic growth or other functional requirements, there are often additional costs associated with bridge expansion and approach roads above and below the structure.

- **Rehabilitation.** Major work required to restore or increase the structural integrity of a bridge, as well as improvements to function, capacity, resilience, or safety. These activities may cost $50 to $100 per square foot to improve a Poor bridge to Fair condition, or $150 to $250 per square foot to raise a bridge to Good condition. Rehabilitation treatments include:

  — *Partial or complete replacement of deck or wearing surface*
  — *Partial or complete replacement of bridge railing*
  — *Retrofit of fatigue-prone steel details*
  — *Retrofit of fracture critical members to add redundancy*
  — *Partial or complete replacement of superstructure*
  — *Bridge strengthening*
  — *Bridge widening*
  — *Bridge jacking to reset bearings or increase vertical clearance*

- **Preservation.** Actions or strategies that prevent, delay, or reduce deterioration of bridges or bridge elements. These activities have costs in the range of $15 to $150 per square foot. Preservation treatments are listed below:

  — *Seal or replace a leaking deck joint*
  — *Removal of deck joints where feasible*
  — *Rehabilitation or replacement of deck drains*
  — *Application of thin overlays on bridge decks*
  — *Installation of rigid deck overlays*
  — *Repair or restoration of major structural elements such as beams, piers, or culverts*
  — *Fiber-reinforced polymer wrap of structural elements*
  — *Painting of steel elements*
  — *Seismic retrofit of superstructure and/or substructure*
  — *Installation of scour countermeasures*
  — *Repair of slope paving*

- **Maintenance.** Condition-based or interval-based activities that do not require engineering or multi-year programming, usually determined by inspectors or local crews. These typically do not improve condition measures but serve to delay deterioration. Typical costs are in the range of $10 to $50 per square foot. Maintenance activities include:

  — *Bridge cleaning on a 1-5 year interval*
  — *Lubrication of bearings and pins on a 2-5 year interval*
  — *Deck sealing on a 3-5 year interval*
  — *Sealing of substructure caps and bearing seats on a 3-5 year interval*
  — *Apply protective coatings on beam ends on a 10-15 year interval or as needed*
  — *Repair of bridge rail deterioration or collision damage*
  — *Minor deck spall repairs or deck crack sealing as needed*
  — *Approach slab repairs or mudjacking*
  — *Cleaning of scuppers and expansion joints as needed*

- *Arrest of steel fatigue cracks, as needed*
- *Removal of channel or culvert debris as needed*
- *Cleaning of brush from under or around bridges as needed*

ADOT considers bridge replacement as an alternative to rehabilitation when the estimated rehabilitation cost exceeds 60% of the replacement cost. Prioritization of replacement and rehabilitation work is based on condition, traffic volume, detour length, usage restrictions (such as load posting), bridge age, functional classification, geometrics, fracture criticality, scour vulnerability, and waterway adequacy.

Preservation work is programmed on bridges that are in generally good structural condition, to maintain good condition at minimal cost. As ADOT continues to implement BrM it is transitioning to greater reliance on quantified life cycle cost where possible. This will be phased in over multiple years as ADOT gains confidence with the forecasting applicable to each type of treatment.

In ADOT bridge management the distinction between rehabilitation and preservation is mainly determined by the severity of defects. Both categories are programmed on a multi-year basis within BrM, both are managed within the same office, and both types of activities can occur within the same project on the same bridge. An ADOT goal for its BrM implementation is to incorporate life cycle cost within the programming process, which may have the effect of increasing the allocation of funds to preservation work.

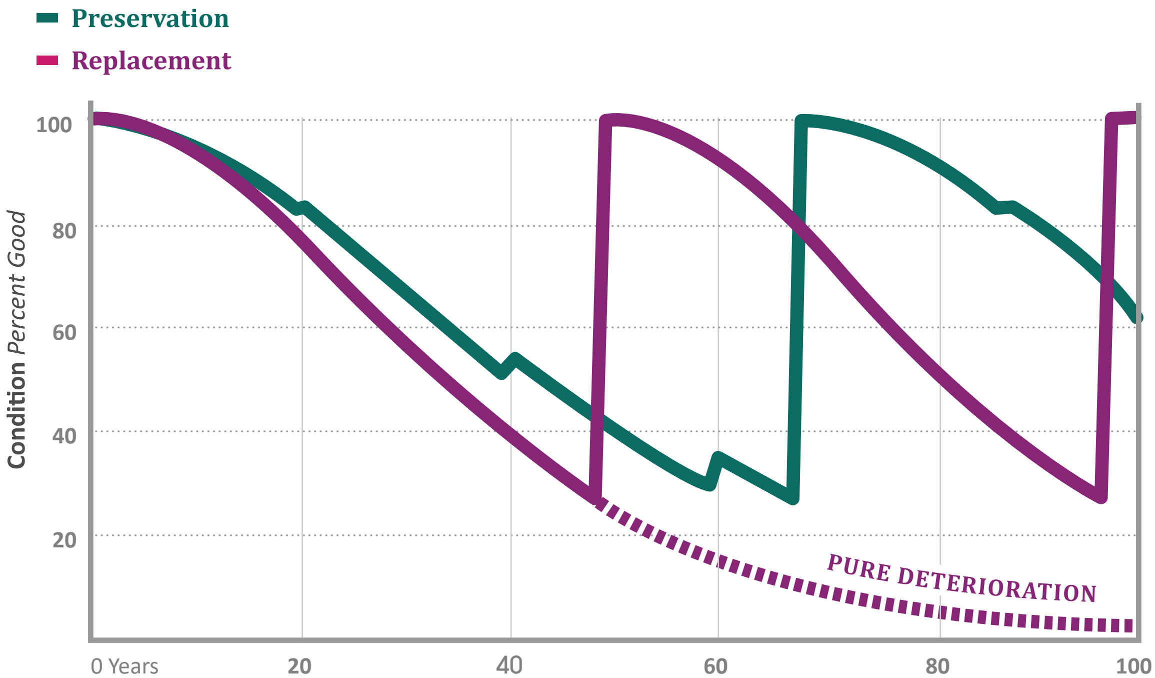
4.3.5 Strategy for minimizing life cycle cost

In recent years, bridge materials and construction methods have vastly improved, enough so that the standard design life for new bridges has increased from 50 years to 75 years. However, most of the existing bridges in Arizona were built before that period of innovation, and some are already past their design life. The reason these bridges continue to serve the public safely, is ADOT's preservation program.

Figure 20 shows the effects of preservation schematically. The lines in the chart show typical condition (in terms of percent Good) over a 100-year period:

- The dotted line is uninterrupted deterioration. If left unrepaired, the bridge would eventually have to be closed for service.
- The solid purple line shows the situation where the bridge is replaced after conditions become intolerable. A replacement cost is incurred.
- The solid green line shows the effects of a preservation program. In this case, preservation or rehabilitation work is performed on an interval of about 20 years, and routine maintenance is also performed. The bridge still must be replaced eventually, but strategically applied preservation treatments can significantly postpone this large replacement cost.

Figure 20 — Effects of Preservation on Bridge Condition



Postponement of large costs resulting from strategic preservation is always of value, as it stretches the benefit of the significant investment the people of Arizona make in their bridges, and reduces overall costs in the long run. ADOT, like all transportation agencies, evaluates this benefit using a discount rate, which has been set by the Department at 3% per year. Given the long lifespan of bridges and uncertainty in the rate of deterioration, ADOT evaluates life cycle costs over a time horizon of 200 years. This may incorporate multiple cycles of preservation and reconstruction.

As previously stated, the bridge LCP analysis investigated two scenarios to determine their effectiveness and long-term benefits to achieve a state of good repair. The analysis was conducted over a 10-year period using funding distributions shown in Table 12. The average annual bridge funding over the next ten years for the SHS is expected to be $82 million and the funding for the NHS is expected to be $59 million.

Table 12 — Expected Annual Bridge Funding Over 10 Years

SCENARIOS	WORST FIRST		PRESERVATION	
	SHS	NHS	SHS	NHS
Maintenance	0	0	$4.1 M (5%)	$2.95M (5%)
Preservation	$0.8M (1%)	$0.6M (1%)	$16.4M (20%)	$11.8M (20%)
Rehabilitation	$78.3 (95.5%)	$55.1M (93.5%)	$32.8M (40%)	$23.6M (40%)
Reconstruction	$2.9M (3.5%)	$3.3M (5.5%)	$28.7M (35%)	$20.65 (35%)
Total	**$82M**	**$59M**	**$82M**	**$59M**

4.3.5.1 Worst First Scenario

This scenario simulated "worst-first" decision making, where only the bridges in worst condition receive any treatment on state-owned bridges. The "worst-first" scenario is not considered to be a realistic future for state-owned bridges, but was developed as part of an analysis to demonstrate the value of bridge preservation. The worst-first scenario involves replacing the worst bridges in the inventory, and conducting virtually no preservation treatments. Output from this scenario is summarized in Table 13.

Table 13 — Results from the Bridge Worst-First Scenario

	INITIAL CONDITIONS		SOGR TARGETS		PROJECTED CONDITIONS	
Bridge Category	**Percent Good**	**Percent Poor**	**Percent Good**	**Percent Poor**	**Percent Good (Year 10)**	**Percent Poor (Year 10)**
SHS	57.3%	1.4%	22.0%	4.0%	17%*	0.8%
NHS	56.6%	1.1%	22.0%	4.0%	16.3%*	0.8%

**The good condition values were statistically extrapolated to reflect the variance in between the BrM element-converted ratings and inspection ratings reported in the NBI and represent approximations for planning purposes*

4.3.5.2 Preservation Scenario

The preservation scenario included a strategically balanced funding allocation between maintenance, preservation, rehabilitation and reconstruction, as shown in Table 12. The results show that this scenario performs better than the worst first scenario for preserving good condition pavements and meeting agency targets over the 10-year period of the plan. Output is summarized in Table 14.

Table 14 — Results from the Bridge Preservation Scenario

	INITIAL CONDITIONS		SOGR TARGETS		PROJECTED CONDITIONS	
Bridge Category	**Percent Good**	**Percent Poor**	**Percent Good**	**Percent Poor**	**Percent Good (Year 10)**	**Percent Poor (Year 10)**
SHS	57.3%	1.4%	22.0%	4.0%	22.9%*	1.1%
NHS	56.6%	1.1%	22.0%	4.0%	22.8%*	0.9%

**The good condition values were statistically extrapolated to reflect the variance in between the BrM element-converted ratings and inspection ratings reported in the NBI and represent approximations for planning purposes*

All the life cycle planning scenarios investigated show that a decline in condition is likely. The analysis is dominated by the aging of the inventory, particularly of certain very large bridges. However, a considerable amount of work will be necessary before this information can be relied upon. The work plan presented in the next section shows what must be done.

4.3.6 Work Plan for Process Enhancements

ADOT is still deep into the process of implementing BrM to update and implement its preservation program. Full implementation requires fully operational software, incorporation of the outputs into routine decision making for the Operating Budget and the Statewide Transportation Investment Program (STIP), evaluation of the effectiveness of delivery of the preservation program, and continuous improvement of planning metrics and preservation and rehabilitation methods. Table 15 presents the work plan for these activities.

Table 15 — Work Plan for Process Improvements – Bridge Life Cycle Planning

Task	Complete	Responsibility
Complete the testing and vetting of AASHTOWare Bridge Management	Dec 2019	Bridge Group and software vendor
Refine BrM decision rules	Jun 2020	Bridge Group
Calibrate BrM models for functional improvements and risk, to assess safety and mobility goals	Jun 2020	Bridge Group
Update BrM life cycle cost analysis and re-evaluate funding and condition targets	Sep 2020	Bridge Group
Obtain senior leadership approval of revised preservation program	Dec 2020	Bridge Group and leadership team
Adjust funding for bridge preservation based on the life cycle cost analysis	Jun 2021	Bridge Group and FMS
Incorporate BrM outputs into STIP development process	Jun 2021	Bridge Group and MPD
Report revised targets to FHWA and local agencies	Jun 2021	Bridge Group and MPD
Further development of deterioration model to fit ADOT data gathered since 2014	Dec 2022	Bridge Group
Further evaluation and improvement	Jun 2023	Bridge Group

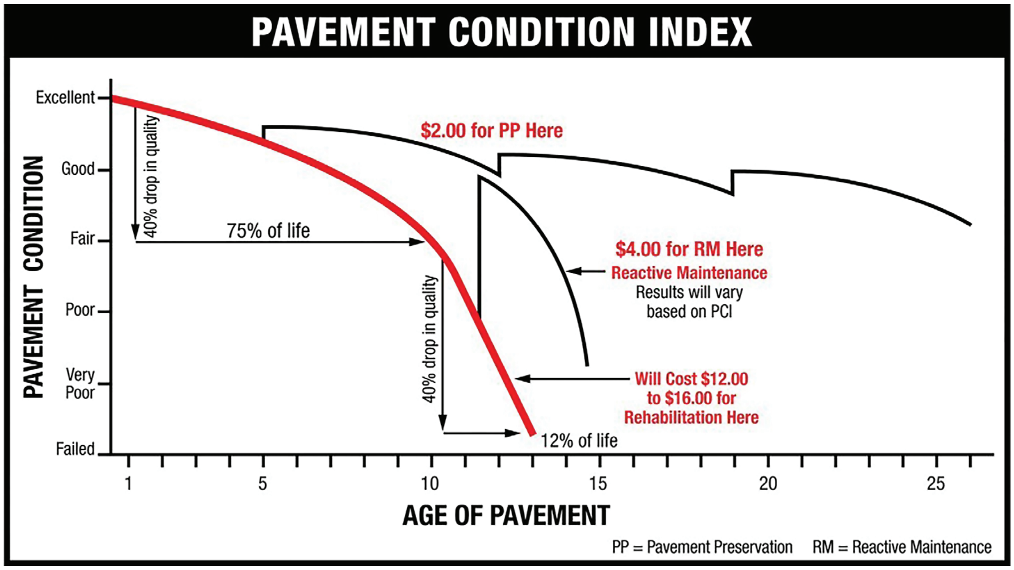
Key:
MPD – ADOT Multimodal Planning Division
FMS – ADOT Financial Management Services
FHWA – Federal Highway Administration

4.4 Pavement Life Cycle Planning

As with bridges, pavements deteriorate with time based on a variety of factors, such as their original design, traffic volumes, truck loads, climatic conditions, underlying condition properties, and construction practices. Most pavements are designed to last 20 years before major rehabilitation or reconstruction is needed, but the timely application of low-cost preservation treatments, such as chip seals, can slow the rate of deterioration and postpone the need for more costly repairs.

This concept is demonstrated in the Pavement Condition Index (PCI) shown in **Figure 21**, which illustrates that spending a small amount for a square foot of pavement preservation periodically in a pavement's life keeps the pavement in good condition for a relatively long period without requiring rehabilitation activities that cost 6 to 8 times as much.

Figure 21 — Illustration of the Cost-effectiveness of Pavement Preservation (PP) Treatments



SOURCE: SUSTAINABLE CITY NETWORK, INC. 2018

The figure also illustrates that spending money on reactive maintenance as a pavement drops into Poor condition is not very economical because the repairs provide only temporary relief of the problem. From a long-term LCP perspective, the most cost-effective and sustainable approach to managing a pavement network includes a combination of planned maintenance, preservation, and rehabilitation activities to sustain pavement performance in Good condition for as long as possible in the most cost-effective manner.

Traditionally, ADOT followed a worst-first strategy for managing its pavement network. Under this approach, some pavement preservation treatments were applied, but most of the available funding was spent on pavements that had deteriorated to the point that only major rehabilitation or reconstruction activities could address the problems. As the state-maintained pavement network ages, this approach to managing the network is not sustainable or cost-effective. An LCP analysis was used to demonstrate the cost-effectiveness of increasing the use of routine maintenance and preservation activities across the state and served as the basis for developing investment strategies towards a state of good repair.

4.4.1 Life Cycle Planning Process for Pavements

The LCP processes certified by FHWA in the initial TAMP envisioned the use of the Deighton dTIMS pavement management system to conduct the analysis. ADOT had planned to complete the configuration and training on the software by fall 2018, but delays have impacted the ability to use the pavement management software to conduct the LCP analysis described in this Section. As an alternative, the LCP analysis was conducted using a sophisticated Excel-based analysis tool that was developed to support other state DOTs with the development of LCP plans. The tool simulates changes in network condition associated with different levels of investment. Although the tool is not as sophisticated as a pavement management system and does not meet the all the requirements outlined in 23 CFR 515.17, it provides a temporary alternative as ADOT completes the implementation of its pavement management software. Future TAMPs are expected to be completed using the dTIMS software.

The tool enabled ADOT to follow its multi-step process for conducting a LCP analysis as outlined below.

- **Form an LCP team.** A pavement task force was created to support the pavement LCP analysis. The group included the TAMP manager, State Maintenance Engineer, Pavement Management Section Manager, Pavement Performance Engineer, and the Surface Treatments Manager.
- **Select the asset classes and networks to be analyzed.** The pavement inventory was subdivided into pavement classes for both NHS and Non-NHS routes. To allow ADOT to consider different LCP strategies and repair costs for each pavement class, the NHS was further broken out into three pavement classes (Interstates, Other NHS State-maintained routes, and Other NHS Locally-maintained routes) and the Non-NHS routes are subdivided into two pavement classes (high and low-volume routes).
- **Establish short- and long-term targets for each asset class.** In addition to the 2- and 4-year targets established for compliance with the Transportation Performance Management rules (23 USC 150), a desired State of Good Repair (SOGR) was established. The desired SOGR was used to compare the results of each LCP scenario to evaluate the level of service that could be achieved at the expected funding level.
- **Define LCP strategies.** In the Excel tool, LCP strategies are developed for each asset class based on expected and desired funding levels over a 10-year analysis period. The strategy development process involves the following steps:
  - — *Linking ADOT's Good/Fair/Poor definitions for pavement condition to different categories of repair. A range of treatments are considered in the tool, including routine maintenance, preservation, major and minor rehabilitation, and reconstruction. Since ADOT estimates that only 10% of the pavements eligible for rehabilitation receive minor rehabilitation, the two rehabilitation activities were combined into one category in the tool, called major rehabilitation, which is applied to pavements in Poor condition.*
  - — *Establishing costs for each of the different levels of repair by pavement class. In other words, the cost of rehabilitation on NHS routes is set at a different level than for Non-NHS routes. The costs for major rehabilitation represent a calculation based on 10% of the cost of minor rehabilitation activities and 90% of the cost of major rehabilitation activities.*
  - — *Establishing deterioration rates for each pavement class and condition category based on the number of years a pavement is expected to stay in that category without additional treatment. The models were used to predict changes in condition over the 10-year analysis period.*
  - — *Distributing the available funding by work type. For instance, one LCP strategy was run with most available funding going to major rehabilitation and reconstruction while another LCP strategy distributed funding between all four treatment categories (i.e., routine maintenance, preservation, major rehabilitation, and reconstruction). For the LCP analysis, a worst first strategy representative of ADOT's past practices was compared to a strategy that allocated between 25 to 55 percent of the funding to routine maintenance and preservation depending on the pavement class.*
- **Set LCP scenario inputs.** The Excel tool used the asset inventory, 2018 pavement condition survey results, expected deterioration rates, and treatment costs as the inputs to the spreadsheet analysis. For the LCP analysis, expected funding levels over the next 10 years were also input into the analysis.
- **Develop LCP scenarios.** By modifying the amount of funding going to each pavement class and treatment type, different strategies can be evaluated. The outputs generated by the tool show the resulting impact on system conditions over 10 years of spending in accordance with each scenario. The resulting outputs summarize the amount of work conducted in each category, the total amount spent, and the percent of the system that meets the desired SOGR so that ADOT could identify the most feasible strategy to minimize life cycle costs while striving to achieve desired pavement conditions.

- **Develop life cycle treatment and cost tables for each asset sub-class.** The LCP planning process resulted in the development of typical life cycle strategies for each pavement class that reflect ADOT's plans to increase investment in maintenance and preservation activities. The resulting treatment strategies are presented in Section 4.4.4. As ADOT implements its pavement management system, the treatment strategies will be reviewed and modified to reflect differences in climatic conditions across the state that were not possible with the Excel tool.
- **Provide input to financial planning.** The results of the LCP analysis were used to inform the investment choices. The tool was used during the financial planning activities to evaluate the various investment strategies under different funding levels and to determine the performance gap between desired and projected conditions. Since the tool recommends investment levels rather than projects, ADOT intends to transition the recommended investment strategies into its pavement management system during calendar year 2019 to inform investment choices in the long-range transportation plan and the 5-Year Transportation Facilities Construction Program section of the STIP.

4.4.2 Drivers of Pavement Performance

In Arizona, the primary drivers that impact pavement performance are related to the following factors:

- **Traffic volumes and loads**, including the effects of heavier truck traffic on pavement deterioration rates across the state.
- **Lack of maintenance and preservation**, due to an historical focus on addressing the pavements in the worst condition first.
- **Climatic conditions**, reflecting the differences across the state in terms of daily temperature variations and freeze-thaw cycles as well as the potential for increases in the number of extreme heat days and in the intensity of individual precipitation events that may lead to flooding.
- **Pavement age**, recognizing that a significant percentage of the pavements on the state-maintained system have exceeded their design life and require extensive repairs.
- **Pavement design and construction**, including the different performance characteristics of each pavement type (e.g., asphalt, concrete, and composite) and the importance of ensuring that good construction practices are used.

Pavement performance characteristics that influence life cycle strategies also impact ADOT's ability to achieve the national goals established under 23 USC 150(b), as described below.

- **Safety.** Keeping pavements in Good condition helps to reduce the likelihood of crashes due to drivers making sudden movements to avoid potholes. Similarly, timely interventions that preserve a pavement's surface characteristics or reduce rutting can have a significant effect on reducing wet-weather accidents and hydroplaning.
- **Infrastructure Condition.** Changes in pavement condition due to normal deterioration influences the feasibility and cost of Maintenance and preservation activities. Pavements that are allowed to deteriorate significantly will require more expensive rehabilitation or reconstruction to address the damage. Therefore, condition is a primary driver of life cycle costs.

- **Mobility.** Although the number of pavement lanes has the most dramatic impact on the ability of traffic to move freely at legal speeds, pavement condition can also impact mobility since vehicles typically travel at slower speeds as pavement condition deteriorates. Mobility is also impacted by work zone closures. ADOT's plans to increase the use of Maintenance and preservation treatments will help to reduce the length of closures associated with more significant rehabilitation and reconstruction projects.
- **Freight Movement.** Pavements have a significant role in ADOT's efforts to address the demands of the commercial sector to increase truck weights and volume. Repeated loading of overweight trucks can shorten pavement life, leading to increased funding requirements to keep the system operational.
- **Environmental Sustainability.** Research indicates that as traffic speeds slow due to mobility or infrastructure condition issues, vehicles create more pollution through greater emissions. Therefore, improvements in pavement condition can contribute to ADOT's targets for Environmental Sustainability. In addition, attention to both the positive and negative impacts on the environment associated with certain treatments may influence life cycle strategies.
- **Project Delivery.** Pavement projects are coordinated with other asset improvements to limit the disruption to the traveling public and help ensure that work is completed on time and within budget.

4.4.3 Forecasting Pavement Condition

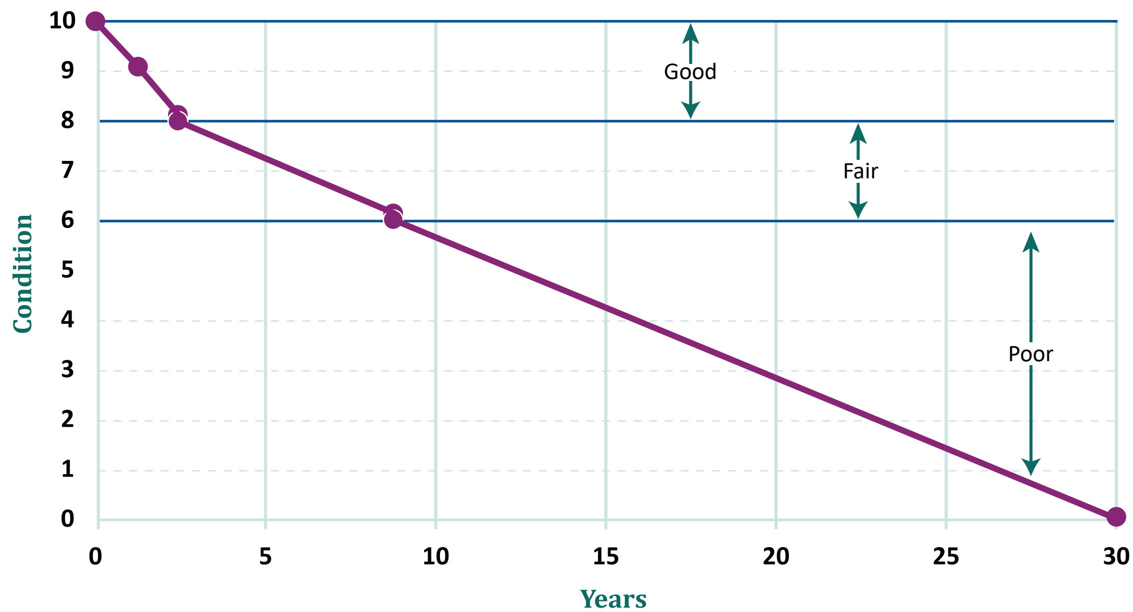
As part of its pavement management system implementation, ADOT is developing new pavement performance models that use the following factors to establish deterioration rates based on historical pavement condition data:

- Functional classification (Interstates and Non-Interstates).
- Climatic conditions.
- Surface type (asphalt, concrete, and composite).
- Last repair (overlay, chip seal).

These factors affect the rate at which a pavement deteriorates, influencing the type of treatment needed and its timing. Therefore, these factors have a significant impact on the life cycle cost of managing the network. Certain treatment strategies, including routine maintenance and preservation, help to slow the rate at which pavements deteriorate, reducing the long-term cost of managing the network and minimizing the near-term inconvenience to the public.

At the time the LCP analysis was conducted, ADOT's pavement performance models were still under development and testing. Even if they had been available to the team, the tool used to conduct the analysis is limited in the sophistication of the performance models that it can use to model pavement deterioration and to forecast future conditions. A linear deterioration model was developed for each pavement class that represents the gradual rate at which a pavement passes from Good condition to Poor condition over its 20-year design life. A graphical representation of the deterioration model used to support the LCP analysis is shown in Figure 22.

Figure 22 — Pavement deterioration model used in the LCP analysis.



The desired SOGR will be achieved by focusing on applying preservation treatments to good condition pavements preventing them from dropping into fair condition while limiting the pavements that fall into poor condition through rehabilitation and reconstruction activities.

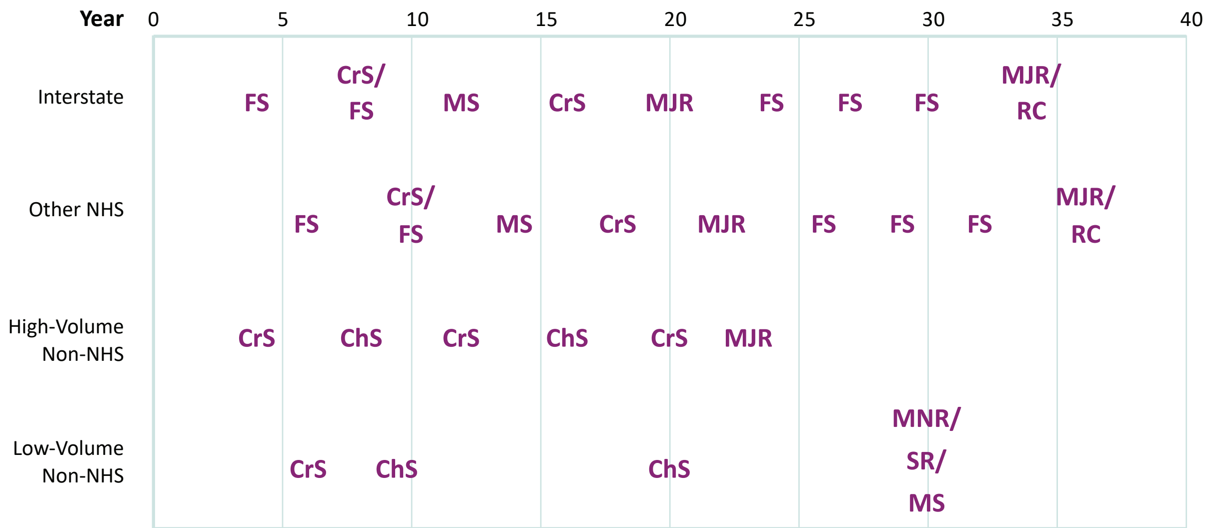
In conjunction with the increased investment in cost-effective treatments, ADOT is also implementing a new pavement management system that will help analyze the changes in performance and optimize long-term costs. Through the combination of increased investment in preservation and improved analysis tools, the Department may be able to improve the percent of the network in Good condition and further reduce the rate at which pavements are deteriorating.

4.4.4 Treatments to Maintain and Improve Performance

ADOT uses a range of treatments to address the needs of the state-maintained pavement network, including routine maintenance, preservation, major and minor rehabilitation, and reconstruction. ADOT's pavement management system has been used in the past to assist with the identification of pavement treatments and timing that optimize pavement life cycle and reduce long-term costs and the new pavement management system is being configured with treatment rules to provide recommendations for each category of repair. In addition, guidelines are available to assist Districts with the scoping of pavement preservation projects intended to extend the useful life of a pavement structure and to address adjacent safety improvements when feasible.

Strategies for maintaining each pavement class were identified based on typical performance to serve as the basis for the pavement deterioration rates and investment strategies that were analyzed during the LCP analysis. The strategies are presented in Figure 23, which shows the types of treatments that are applied and the typical timing for applying those treatments. It was noted that due to funding constraints, the Non-NHS routes are typically maintained with low-cost treatments since funding is not adequate to perform reconstruction on this portion of the network.

Figure 23 — Representative pavement treatment strategies currently being applied



Treatments included are: Fog Seal (FS), Crack Seal (CrS), Microsurfacing (MS), Major Rehabilitation (MJR), Reconstruction (RC), Chip Seal (ChS), Minor Rehabilitation (MNR), Spot Repair (SR)

Since the Excel-based tool used for LCP uses treatment categories rather than specific types of treatments, each of the treatments represented were classified into the categories described below. Treatment costs were estimated in the first quarter of 2019.

- **Routine and Preventative Maintenance.** Maintenance includes treatments such as crack sealing intended to keep moisture from getting into the underlying layers and and fog sealing which protects or restores an oxidized asphalt surface. Maintenance is applied to pavements in Good condition. The average cost of treatments in this category is $20,000 per lane mile.
- **Preservation.** This category includes low-cost treatments that are applied to pavements in Fair condition to slow the rate of deterioration and/or address surface characteristics. Preservation treatments are not designed to add structure to the pavement. This category includes a range of treatments, but chip seals and microsurfacing are probably most common. ADOT is undertaking a pavement life extension test project to evaluate the cost-effectiveness of two types of cape seals as additional preservation options. The cost of treatments in this category range from $72,100 to $80,500 per lane mile.
- **Rehabilitation.** This category includes both major and minor rehabilitation activities that address surface deterioration and add structure to the existing pavement. Minor rehabilitation treatments include friction course replacements, thin (1-2.5 inch) overlays, and spot repair to pavements without major structural deterioration. More commonly, major rehabilitation treatments, which include milling off the existing surface and replacing it with 4.5 to 5 inches of asphalt, are applied to pavements in Poor condition with significant amounts of deterioration present. Traditionally, major rehabilitation has been the most common treatment used by ADOT. A weighted average cost ranging from $220,000 to $359,000 per lane mile (between typical costs for minor and major rehabilitation) was used for treatments in this category.
- **Reconstruction.** Reconstruction is applied to a pavement when both the surface and underlying layers need to be replaced. Reconstruction is the most expensive of all the treatment options, so strategies that defer the need for this type of treatment help reduce life cycle costs. The average cost of reconstruction in Arizona ranges from $636,000 to $1,062,000 per lane mile.

4.4.5 Strategy for Minimizing Life Cycle Cost

The LCP analysis was conducted using two scenarios intended to demonstrate the cost-effectiveness and long-term benefits to ADOT's plans to increase the amount of routine maintenance and preservation treatments that will be applied. The analysis was conducted over a 10-year period using the inputs described earlier in this Section. Both strategies used the same amount of funding, but the distribution of funding by treatment category varied. The total amount of funding used in each of the 10 years is shown in Table 16. The State Pavement Budget is assumed federal and state highway funds used for state highways only.

Table 16 — Assumed Funding over 10 Years

Fiscal Year	State Pavement Budget (in millions)	Local Pavement Budget (in millions)
2019	$247.5	$38
2020	$216.5	$38
2021	$152.5	$38
2022	$179.5	$38
2023	$217.5	$38
2024	$205.5	$38
2025	$277.5	$38
2026	$297.5	$38
2027	$297.5	$38
2028	$317.5	$38

4.4.5.1 Worst First Scenario

The first strategy represents an investment approach that is similar to the approach ADOT has used historically, with an emphasis on major rehabilitation and reconstruction activities to address deteriorated pavement. Under this scenario, all the available funding for the Non-NHS routes is allocated to major rehabilitation and reconstruction. For the NHS routes, some funding was allocated to preservation activities because the current condition of that portion of the network is so good, that there were not enough miles of pavement in Poor condition to use the available funding. The distribution of funding for pavements under the worst first scenario is presented in Table 17.

Table 17 — Distribution of Funding for Pavements Under the Worst-first Scenario

Pavement Class	% of State Funding Allocated	% of Local Funding Allocated	% of Budget for Each Pavement Class Allocated to Repair Types: Do Nothing	Routine Maintenance	Preservation	Major Rehabilitation	Reconstruction
NHS – Interstates	32%	0%	0%	0%	5%	50%	45%
Other NHS -State	36%	0%	0%	0%	0%	55%	45%
Other NHS -Local	0%	100%	0%	0%	0%	25%	75%
Non-NHS -High Volume	7%	0%	0%	0%	0%	90%	10%
Non-NHS – Low Volume	25%	0%	0%	0%	0%	90%	10%

The outputs from the scenario are presented in Table 18.

Table 18 — Pavement results for the worst-first scenario (excludes ramps and frontage roads)

		NHS*			NON-NHS**	
Pavement Class:		Interstates	Other NHS – State	Other NHS – Local	High Volume	Low Volume
Total Miles:		5,200	5,673	1,592	1,119	8,189
Initial Mileage	# Good	2,560	1,950	27	308	2,261
	% Good	49%	34%	2%	28%	28%
	# Poor	40	173	108	41	278
	% Poor	1%	3%	7%	4%	3%
SOGR Targets	% Good	58%	40%	5%	35%	30%
	% Poor	1%	3%	8%	4%	7%
Resulting Mileage After 10 Years	# Good	2,445	738	253	133	699
	% Good	47%	13%	16%	12%	9%
	# Poor	<1	3,058	475	653	5,765
	% Poor	<1%	54%	30%	58%	70%

**NHS based on 2017 through lane miles and ramps where updated quality controlled condition data was available at the time of the analysis.*
*** Non-NHS based on 2017 condition data. Includes passing lanes, auxillary lanes, ramps, and frontage roads.*

As shown in the last four rows, over the 10-year period considered in the analysis, the SOGR targets for percent of the network in Good condition are not achieved for any part of the network other than the local-maintained NHS, but the predominant focus on pavements in Poor condition results in a large percent of the network deteriorating to Poor condition, with 70% of the low-volume Non-NHS network in Poor condition.

4.4.5.2 Preservation Scenario

A second scenario was considered in which funding was distributed to include all the treatment categories, so most of the network is preserved in Good and Fair condition rather than allowed to deteriorate to the Poor condition. The lower treatment costs associated with applying routine maintenance and preservation before significant deterioration is present have a significant impact on the condition of the network, even when the same total amount of funding is used for the analysis.

For the preservation scenario, the funding allocations to each pavement class and treatment type were intended to preserve or improve pavement conditions as much as possible with the expected level of funding. The allocations made under the preservation scenario are shown in Table 19. These allocations were made to illustrate the improved conditions that are achievable with an on-going commitment to investments in routine maintenance and preservation, but they also reflect a level of investment that ADOT considers to be implementable, as reflected in the 10-year investment strategies presented in Section 7.

Table 19 — Distribution of funding for pavements under the preservation scenario

			Percent of Budget for Each Pavement Class Allocated to Repair Types				
Pavement Class	% of State Funding Allocated	% of Local Funding Allocated	Do Nothing	Routine Maintenance	Preservation	Major Rehabilitation	Reconstruction
NHS – Interstates	32%	0%	0%	8%	32%	56%	4%
Other NHS -State	36%	0%	0%	8%	36%	55%	1%
Other NHS – Local	0%	100%	0%	5%	15%	55%	25%
Non-NHS – High Volume	7%	0%	0%	6%	42%	51%	1%
Non-NHS – Low Volume	25%	0%	0%	15%	52%	33%	0%

The results from the analysis of the preservation scenario are presented in Table 20. The results reflect significant improvement in the portion of the pavement network in Good condition, but they also show that fewer pavements fall into Poor condition, so the SOGR targets are met at the end of the analysis period.

Table 20 — Pavement results for the preservation scenario (excludes ramps and frontage roads)

		NHS*		NON-NHS**		
Pavement Class:		**Interstates**	**Other NHS – State**	**Other NHS – Local**	**High Volume**	**Low Volume**
Total Miles:		5,200	5,673	1,592	1,119	8,189
Initial Mileage	**# Good**	2,560	1,950	27	308	2,261
	% Good	49.2%	34.3%	1.7%	27.5%	27.6
	# Poor	40	173	108	41	278
	% Poor	0.7%	3.0%	6.8%	3.7%	3.4%
SOGR	**% Good**	58%	40%	5%	35%	30%
	% Poor	1%	3%	8%	4%	36%
Resulting Mileage After 10 Years	**# Good**	3,036	2,310	538	416	2,493
	% Good	58%	41%	34%	37%	30%
	# Poor	<1	170	117	40	2,937
	% Poor	<1%	3%	7%	4%	36%

**NHS based on 2017 through lane miles and ramps where updated quality controlled condition data was available at the time of the analysis.*
*** Non-NHS based on 2017 condition data. Includes passing lanes, auxillary lanes, ramps, and frontage roads.*

4.4.5.3 Approach to Process Enhancements

ADOT considers the development and implementation of its pavement preservation program to be a work in progress that will require a long-term commitment to be successful. The initial 30% increase in preservation funding identified in ADOT's approved Long-Range Transportation Plan (*What Moves You Arizona 2040*) and the planned investments outlined in **Section 6** demonstrate the agency's commitment to slowing the rate at which the pavement network deteriorates while also allocating funds to restore the aging assets that have already undergone significant deterioration.

A key to ADOT's success at implementing the recommended LCP strategy is completing the implementation of the pavement management software so that it can be used to help identify appropriate treatments and timing. ADOT is on track to complete the implementation by August 2019. Once the implementation is completed, ADOT will rerun the pavement analyses using dTIMS and make any necessary adjustments to the condition targets and planned investments. In the future, ADOT will use the pavement management system to drive project and treatment selection as part of the STIP development process. The ADOT Pavement Management Section is responsible for completing the implementation of the pavement management software. **Table 21** presents the work plan for these activities.

Table 21 — Work Plan for Process Improvements – Pavement Life Cycle Planning

Task	Complete	Responsibility
Complete the testing and vetting of dTIMS	Dec 2019	Pavement Section and Software Vendor
Refine decision rules	Jun 2020	Pavement Section
Calibrate performance models	Jun 2020	Pavement Section
Update benefit cost analysis and re-evaluate funding and condition targets	Sep 2020	Pavement Section
Obtain senior leadership approval of revised preservation program	Dec 2020	Pavement Section and leadership team
Adjust funding for pavement preservation based on the analysis results	Jun 2021	Pavement Section and FMS
Incorporate dTIMS outputs into STIP development process	Jun 2021	Pavement Section and MPD
Report revised targets to FHWA and local agencies	Jun 2021	Pavement Section and MPD
Further development of deterioration model to fit ADOT data gathered since 2014	Dec 2022	Pavement Section
Further evaluation and improvement	Jun 2023	Pavement Section

Key:
MPD – ADOT Multimodal Planning Division
FMS – ADOT Financial Management Services
FHWA – Federal Highway Administration

Section 5
Risk Management

5.1 Overview

The importance of risk management is highlighted by the MAP-21 requirement to develop a risk-based asset management plan for the NHS. FHWA defines risk as ***"the positive or negative effect of uncertainty or variability on agency objectives."***

Risk management is defined as "the processes and framework for managing potential risks, including identifying, analyzing, evaluating, and addressing the risks to assets and system performance." (23 CFR Part 515.5). Risk management strengthens asset management by identifying strategies to either reduce, mitigate or manage risk effects on ADOT's asset management objectives. This section describes ADOT's risk policy and procedure, risk management process, and risk mitigation plans for high priority risks for the entire state system (NHS and non-NHS). Additionally, this section summarizes an assessment of NHS pavements and bridges repeatedly damaged by emergency events, consistent with Federal requirements.

5.2 Risk Policy and Procedure

The foundation of risk-based asset management is an agency commitment to adopt policies and procedures that support the identification, analysis and treatment of risks.

An ADOT-FHWA sponsored *Transportation Asset Management Implementation Plan* prepared by Cambridge Systematics (2015) concluded that while:

> *"ADOT considers risk management concepts in some of its business practices.... the agency does not have a systematic, formal process for evaluating risks associated with its asset management programs." The Plan also indicated that, "longer term, ADOT should develop a more comprehensive approach for considering risk in the asset management process."*

By formally adopting a risk management process, ADOT could potentially reap the following benefits in the management of assets:

- Reduce crisis management by anticipating likely risks and developing strategies to avoid or mitigate them.
- Enable risk to be factored into the selection of an asset improvement alternative or investment option.
- Identify the positive aspects of risk so the agency can prepare to benefit from potential opportunities.
- Aid communication with stakeholders regarding the risks and uncertainties associated with different asset management solutions, including no action alternatives.
- Facilitate the assignment of risk management duties to the appropriate parties.
- Help make the case for allocating adequate resources to asset preservation in a transportation plan or program.

Following the initial Asset Management Risk Workshop in January 2018, ADOT conducted a second iteration in February 2019, which was attended by key agency personnel, including subject matter experts who updated the initial ADOT asset management risk register. In addition to updating the risks themselves, priority scores and mitigation measures were also updated. The outcome of this effort is described below.

5.3 Risk Management Process

ADOT followed the basic risk framework identified in the FHWA guidance document titled, "Incorporating Risk Management into Transportation Asset Management Plans." The framework includes five components:

- **Establish Context.** This step includes the identification of agency asset management goals, objectives and targets. This can include objectives for the risk process itself. Much of the context for ADOT's TAMP was established during the January 2018 Risk Workshop.
- **Risk Identification.** This step includes the identification of risks to condition, performance and facilities that are repeatedly damaged by emergency events. ADOT's Pavement Section and representatives from the Geotechnical Section reviewed each highway in the State and identified geotechnical risks by mileposts. This information was incorporated into the risk module of the pavement management software. Risks to bridges such as scour have been previously identified and documented in reports that are used to inform funding decisions. Repeated emergency events were identified by ADOT's Maintenance Group with the assistance from Financial Management Services. Other risks were identified in the 2018 and 2019 risk workshops.
- **Risk Analysis.** This step estimates the magnitude of risk impacts by assessing the likelihood and consequence of each risk identified. This was one of the primary activities undertaken at the risk workshops.
- **Risk Evaluation.** This step prioritizes the risks and was undertaken at the risk workshops.
- **Manage Risks.** This step involves the preparation of a mitigation plan for top priority risks and for repeated emergency events. This effort was undertaken as part of the preparation of the TAMP.

ADOT seeks for its risk-based asset management to:

- Be comprehensive.
- Be easy to understand.
- Prioritize risks.
- Identify long-term vulnerabilities.
- Identify strategies for the prevention and avoidance of risks.
- Inform decision-making.
- Identify the appropriate party to manage the risks.
- Monitor top priority risks.
- Aid in the prioritization of projects in the STIP.
- Support communication regarding asset management with stakeholders, including the public.

To be comprehensive, this plan considers several levels of risk (Table 22).

Table 22 — Risk Type

Risk Type	Effect
Agency	Risk to the agency that affects the implementation of the strategic goals of the asset management plan. Examples include changes in leadership, legislative actions, unfunded mandates and the ability to convey the importance of asset management to decision-makers and the public.
Financial	Affect the availability of adequate funding or accurate prediction of future funding needed to implement the TAMP. Examples include inflation, unexpected funding shortfalls, solvency of the Highway Trust Fund, financial markets, interest rate increases and inaccurate predictions in financial plans.
Program	Affect the ability to deliver a program of projects in a timely manner and meet performance targets. Risks may include the inability to effectively manage data, the loss of institutional knowledge via attrition, competing spending priorities, inaccurate cost-estimates and construction/materials price volatility.
Asset	Affect individual assets, such as structural deterioration, extreme weather and obsolescence. Assets risks include flooding, landslides, hazardous materials spills, collisions with bridge elements and assets that do not meet current design standards.
Project	Associated with projects to restore or replace individual assets. An example of a project risk is the impacts associated with lengthy construction detours in areas where redundant, alternative routes don't exist. Project delivery risks include delays caused by environmental, utilities, right-of-way, geotechnical, procurement, scope creep and inter-governmental agreements.
Activity	Associated activities like routine maintenance, including slow or inadequate response to damaged assets (e.g., pothole or guard rail repair) or extreme weather events (e.g., clearing blocked drainage structures, repairing scour weakened bridge foundations or risks to workers such as heat, fires, etc.).

5.3.1 Risk Register

An easy to understand and commonly used tool to identify, evaluate and prioritize risks is known as a risk register. Using a risk register, the significance and priority of a risk event (R) is determined by considering both the seriousness of the consequences (C) if the event occurs and the likelihood (L) that it will occur; in other words, L x C = R. A color-coded "heat" scale assists in the evaluation of risks (Table 23).

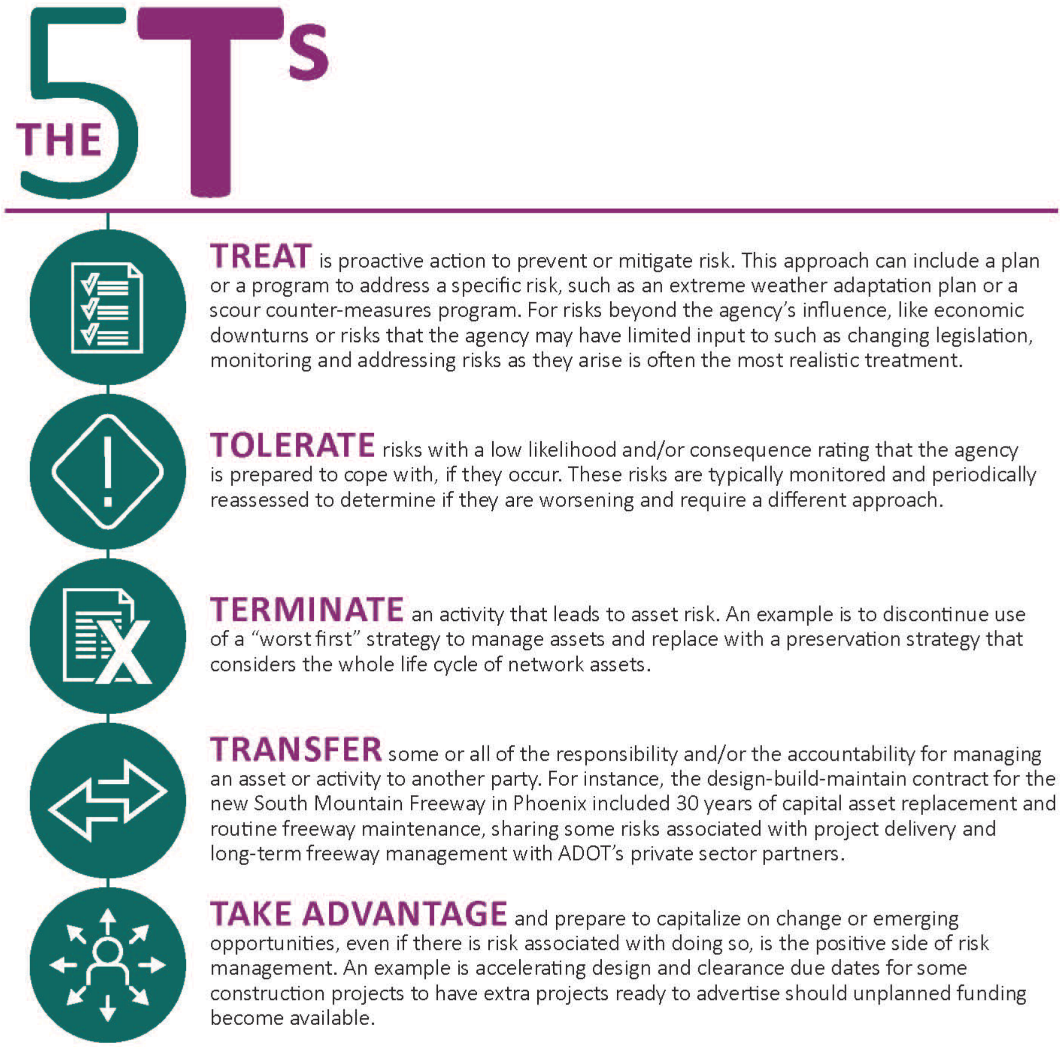
The Risk Register also contains a summary of mitigation steps to address risks. The "five Ts" (Figure 24) is a commonly used way of describing the options for the treatment of asset risk.

Table 23 — Risk Rating Matrix – Heat Map

	CONSEQUENCE				
Likelihood	**Negligible (1)**	**Low (2)**	**Medium (3)**	**Very High (4)**	**Extreme (5)**
Almost Certain (5)	L (5)	M (10)	H (15)	VH (20)	VH (25)
Likely (4)	L (4)	M (8)	M (12)	H (16)	VH (20)
Possible (3)	L (3)	M (6)	M (9)	M (12)	H (15)
Unlikely (2)	L (2)	L (4)	M (6)	M (8)	M (10)
Rare (1)	L (1)	L (2)	L (3)	L (4)	L (5)

‡R = Risk Rating; categories include Low (1-6) = L, Medium (7-13) =M, High (14-19) =H, Very high (20-25) =VH

Figure 24 — Five Ts



SOURCE: FHWA 2012A

The following Risk Register contains the risks, ratings, risk owner and a high-level summary of the recommended risk mitigations that were identified at the Asset Management Risk Workshop (Table 24) along with a corresponding heat scale rating. Although this TAMP focuses on bridges and pavements, the risk analysis was not limited to these assets. All the risks identified in the Risk Register could affect state-owned NHS and non-NHS routes. More detailed descriptions of the mitigations for the high and very high priority risks (>14) are presented beneath the Risk Register.

Table 24 — Asset Management Risk Register

Risk Category	Risk Event (Risk Owner)	L*	x	C†	=	R‡	Risk Mitigation	Heat Type
AGENCY	**Changing legislation** (Government Relations)	5	x	4	=	20	Monitor proposed State and Federal legislation and communicate impacts to management, the Transportation Board, the Governor and Legislature.	VERY HIGH
	Effectively communicating asset needs (Asset Groups, Multimodal Planning Division [MPD])	3	x	4	=	12	Share output of TAMP with decision-makers. Adjust Recommended Investment Choice (RIC) to allocate adequate preservation funding for maintenance of pavement and bridge assets	MEDIUM
	Extreme weather trends (Environmental Planning Resilience Program, Districts, Transportation System Management & Operations [TSMO])	5	x	4	=	20	Implement the recommendations of ADOT's Resilience Program plan including pilot programs for a pump station reliability tool, probabilistic bridge asset class deterioration modeling, an operational Resilience GIS database, and a weather and flood monitoring dashboard.	VERY HIGH
	Ability to accurately forecast asset performance (MPD, Asset Groups)	3	x	4	=	12	Refine data collection practices and bridge and pavement management system deterioration models over time.	MEDIUM
	Expansion without new maintenance funding (MPD, TSMO, FMS)	2	x	2	=	4	Evaluate the true costs of infrastructure maintenance activities. Communicate impacts to Transportation Board.	LOW
	Inadequate preservation funding for the existing system (MPD, Asset Groups, Financial Management Services[FMS])	5	x	5	=	25	Identify funding gaps and investment strategies that could close those gaps in the TAMP. Continually inform management, the Transportation Board, the Governor and Legislature about the potential impacts of preservation funding shortfalls.	VERY HIGH
FINANCIAL	**Changing interest rates and inflation** (FMS, MPD)	4	x	2	=	8	Prepare financial forecasts, fiscally-constrained programming, monitor and address.	MEDIUM
	Viability of Revenue Sources (FMS, MPD)	5	x	5	=	25	Prepare revenue forecasts, fiscally-constrained programming, monitor and address.	VERY HIGH
	Liability losses associated with assets (Risk Management)	3	x	5	=	15	Self and supplemental Insurance.	HIGH
	Losses caused by third parties (Risk Management)	5	x	3	=	15	ADOT Insurance Recovery Unit pursues reimbursement from at fault third parties.	HIGH

Risk Category	Risk Event (Risk Owner)	L*	x	C†	=	R‡	Risk Mitigation	Heat Type
PROGRAM	**Ability to collect accurate asset and performance data** (MPD)	4	x	4	=	16	Invest in data management and automated data collection.	HIGH
	Obsolete infrastructure (Asset Groups, MPD)	5	x	3	=	15	Evaluate obsolete asset features during project scoping and recommend cost effective improvements.	HIGH
	Staff attrition (State Engineer's Office)	5	x	3	=	15	Cross-training, succession plan. Hire more in-house staff.	HIGH
	Construction/materials price volatility (FMS, Contracts and Specifications)	5	x	5	=	25	Price adjustments for volatile commodities – contingency fund. Move projects to future years.	VERY HIGH
	Competing spending priorities (MPD, FMS)	5	x	3	=	15	P2P process to prioritize projects. Address in the Long-Range Transportation Plan and monitor the Annual System Performance Report to determine preservation trends and progress moving towards performance targets.	HIGH
PROJECT	**Scope creep potentially increasing costs and leading to project delivery delays** (MPD, Project Review Board, PPAC, FMS)	5	x	1	=	5	Planning-level scoping to provide clear definition to the project needs. Control at Project Review Board and the Priority Planning Advisory Committee.	LOW
ASSET	**Flood damage including scour** (Bridge Group, TSMO, Environmental Planning Resilience Program)	5	x	4	=	20	Statewide scour evaluation; scour-counter measures program. Continue implementation of ADOT's Resilience Program plan and ADOT/USGS post flood modeling capabilities.	VERY HIGH
	Collision damage to bridges (Bridge Group, Risk Management)	5	x	3	=	15	ADOT Insurance Recovery Unit pursues reimbursement from at fault third parties.	HIGH
	Permitted over-weight load related damage (TSMO, Enforcement and Compliance Division [ECD], Asset Groups)	4	x	3	=	12	Monitor impacts of overweight loads and adjust permitting accordingly.	MEDIUM
	Non-permitted overweight load related damage (MPD, ECD)	5	x	3	=	15	More weigh-in-motion infrastructure; increased resources for enforcement; awareness training for enforcement officers	HIGH
	Landslides and/or slope failures (Geotechnical Section)	2	x	5	=	10	Identify unstable areas, remediate storm water infiltration, re-contour or stabilize slopes, install monitoring devices.	MEDIUM
	Rock fall (Geotechnical Section, District Maintenance)	5	x	1	=	5	Identify unstable areas, rock fall mapping, monitoring, rock fall prevention projects. Consider creating a fund for this ongoing challenge.	LOW

Risk Category	Risk Event (Risk Owner)	L*	x	C†	=	R‡	Risk Mitigation	Heat Type
	Retaining wall failures (Geotechnical Section)	1	x	5	=	5	Screen wall products in the Product Evaluation Program. Perform routine retaining wall inspections and maintenance, identify failing walls, initiate repair or replacement projects.	LOW
	Events inside tunnels resulting in loss of service (Bridge Group, TSMO)	1	x	5	=	5	Routine, comprehensive tunnel inspections and maintenance. Replace obsolete lighting. Emergency response plan.	LOW
	Failure of small (<20 feet in span parallel to the roadway) culverts (TSMO)	1	x	5	=	5	Statewide small culvert evaluation, consider culvert upgrades when developing pavement projects.	LOW
	Lack of redundant routes if an asset fails (TSMO, Asset Groups)	3	x	5	=	15	Update emergency detour plans, electronic signage, identify vulnerable assets and maintain in good condition. Consider the development of Flex lanes.	HIGH
ACTIVITY/ OPERATIONS	**Inadequate maintenance budget** (TSMO, FMS)	5	x	5	=	25	Defer maintenance, inform legislators of impacts.	VERY HIGH

**L = Likelihood; categorized as Rare (1), Unlikely (2), Possible (3), Likely (4), Almost certain (5)*
†C = Consequence; categorized as Negligible (1), Low (2), Medium (3), Very high (4), Extreme (5)
‡R = Risk Rating; categories include Low (1-6), Medium (7-13), High (14-19), Very high (20-25)

5.3.2 Mitigation for High Priority Risks

Many of the risks identified are known to the agency and have formal or informal strategies in place for mitigation. Others were identified as part of this risk analysis effort. ADOT's risk mitigation strategies for high priority risks follow.

5.3.2.1 Changing Legislation

The Government Relations Office is responsible for coordination and oversight of ADOT legislative initiatives, rules and policies. The office provides a proactive process through which ADOT communicates with and serves Arizona's Congressional Senators and Representatives, State Legislators, Governor's Office and the people of Arizona as the central communication point to ensure the priority of ADOT's mission is reflected in state and Federal legislation, rules and policies.

During Federal and state legislative sessions, the office tracks bills and informs ADOT's executive team of issues that may affect the agency. The office works closely with ADOT staff to gather information to assist the Governor's Office and legislators to assess the impacts of proposed legislation/rules on the agency, highway system or revenues available for transportation purposes. Identifying potential legislative issues early provides the agency an opportunity to comment and potentially influence the outcome.

5.3.2.2 Extreme Weather

ADOT prepared a *Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona* (March 2013) (Appendix A) and an *Extreme Weather Vulnerability Assessment* (January 2015) (Appendix A). Study findings include:

- **Extreme Heat.** The number of days exceeding 100°F annually is predicted to double in low desert areas by 2080. Impacts could include pavement deformation, shorter pavement construction windows, heat-related worker safety issues and public safety issues during lengthy delays. Higher temperatures would stress vegetation, thereby reducing ground cover contributing to increased dust storms. Wildfires also would be more likely and larger in mountainous areas where temperatures are expected to increase as well. Burned areas are subject to increased runoff potentially overwhelming roadway drainage structures. Benefits include less freeze-thaw impacts to pavement and less snow removal in the high country.
- **Extreme Precipitation.** Increases in yearly rainfall are expected to be modest, but there is the potential for more intense individual precipitation events which may damage or overwhelm drainage structures and pump stations. Soils that are saturated during intense rain events contribute to an increased risk of rock fall or landslides.

The *Extreme Weather Vulnerability Assessment* recommended the systematic integration of extreme weather risks into the TAMP as well as the incorporation of cost-effective adaptation strategies. To accomplish this, ADOT has prepared an *Asset Management, Extreme Weather, and Proxy Indicators Infrastructure Resilience Report* (February 2019) (Appendix A). Recommendations for improving resilience include:

- Roadside Vegetation Management Guidelines (implemented)
- Probabilistic Bridge Design Pilot Project (underway)
- 2019 Pump Station Reliability Tool Pilot Project (underway)
- Scour Counter Measures Program (implemented)
- Culvert Repair Program (implemented)
- Geo-hazard Plan (plan completed – implementation unfunded)
- ADOT's Environmental Planning Group is currently managing the infrastructure resilience project.

5.3.2.3 Inadequate Preservation Funding for the Existing System

SHS bridges and pavements are aging, making them costlier to maintain. At the same time the highway system continues to expand, adding to the costs of maintaining the system. The resources available for preservation haven't kept up with needs, resulting in an increasing amount of deterioration of SHS bridges and pavements. To address this issue, ADOT is increasing its investment to preserve Arizona's highway assets. WMYA 2040 recommends investing $326 million annually for asset preservation, about 30% more than the funding identified in the previous long-range plan. Although it will take until 2025 to fully phase in this funding level, this long-term financial commitment sets ADOT down the path to preserve aging bridge and pavement assets.

5.3.2.4 Viability of Revenue Sources

The Great Recession of 2007-2009 impacted ADOT's ability to fund asset preservation, contributing to a deterioration of asset condition. Although the economy has improved, future economic downturns could have an even bigger effect as legacy assets will require more and more funding to preserve as they age. Transportation revenues are not keeping pace with needs, making it difficult to adequately fund expansion, modernization and preservation projects. The solvency of the Federal Highway Trust Fund and the availability of Federal funds in future years may create a revenue risk. The expiration of local transportation excise taxes, and the decline of gas tax revenues, would also have a significant effect on revenues. Further, transportation excise taxes are highly sensitive to economic cycles. If reduced revenues occur, ADOT's ability to meet performance targets could be impacted.

ADOT's *Long-Range Transportation Plan* process evaluates different revenue and investment scenarios and considers revenue variations when recommending investment choices. Additionally, ADOT's planning and programming process is putting an increasingly high priority on preservation projects for bridges and pavements. FHWA's decision to allow Federal funds to be used on certain types of preservation activities has increased the state's flexibility to adjust to funding shortfalls. ADOT actively monitors revenues and prepares monthly financial reports for management and State Transportation Board review.

5.3.2.5 Liability Losses

ADOT's *2017 Comprehensive Financial Report* states that:

> *"The Department is exposed to various risks of loss related to torts; thefts of, damage to, and destruction of assets; errors and omissions; injuries to employees; and natural disasters. The Department is a participant in the State's self-insurance program and, in the opinion of the Department's management, any unfavorable outcomes from these claims and actions would be covered by the self-insurance program. Accordingly, the Department has no risk of loss beyond adjustments to future years' premium payments to the State's self-insurance program."*

It should be noted that while premiums paid to the State's self-insurance program have not increased in recent years, transportation liability losses have caused the State's insurers to increase retention amounts (deductibles) and premiums for excess coverage.

5.3.2.6 Losses Caused by Third Parties

One way to reduce direct property loss (state highway items not covered by the State's self-insurance program) is to increase the amount recovered from the responsible party (**Table 25**). In 2014, ADOT initiated an effort to improve the recovery process and increase the insurance recovery rate. The process improvement drove the recovery rate from 63% in fiscal year (FY) 2014 to 107% in FY 2018.

Table 25 — Insurance Recovery Metrics - Dec 2017 (year-to-date)

Year	Recoveries	Repairs	Recovery Rate
FY2014	$3,084,575	$4,860,045	63%
FY2015	$2,800,930	$5,061,118	55%
FY2016	$4,938,565	$5,945,449	83%
FY2017	$5,341,978	$5,399,292	99%
FY2018	$6,524,673	$6,124,784	107%
FY2019*	$2,324,533	$2,244,134	104%
AVERAGE	**$4,169,209**	**$4,939,137**	**86%**

**FY2019 Year-To-Date*

SOURCE: ADOT ADMINISTRATIVE SERVICES DIVISION

5.3.2.7 Ability to Collect Accurate Asset and Performance Data

In 2017, ADOT adopted a new automated process for collecting certain types of pavement condition data. The new automated process utilizes different methodologies and protocols than the manual processes that were previously used. Thus, the data collected using the previous methods do not correlate with the new automated data, making development of trend lines for performance reporting challenging. Moreover, verifying the new data collection process has required an extensive quality control process which has delayed the ability to use the new data for the development of deterioration curves for ADOT's new pavement management system.

5.3.2.8 Asset Obsolescence

A cost-effective way to accommodate increased travel and freight demand is to improve obsolete asset infrastructure. Low bridge clearances and outdated roadway geometry may prevent highways from being used as truck routes and require lower speed limits, ultimately diminishing system efficiency. To address this issue, obsolescence will be evaluated during project scoping. Reasonable upgrades that improve roadway operating efficiencies will be considered for inclusion in the recommended project.

5.3.2.9 Staff Attrition

In recent years, ADOT has been increasingly relying on consultants and contractors to perform certain duties. At the same time, the agency continues to lose highly experienced engineers and other professional staff to retirement or external opportunities. This has diminished institutional knowledge and reduced the number of potential knowledgeable candidates available for promotion into management positions.

To address this issue, ADOT is initiating a Succession Development Plan that prepares individuals for possible promotion to mission critical positions. The elements of the plan include providing one-on-one coaching, management training classes and cross-functional training to provide opportunities for employees to move up in the agency and allow knowledge transfer before losing experienced staff.

5.3.2.10 Construction/Materials Price Volatility

ADOT has formed a Construction Cost Escalation Risk Analysis Panel to evaluate construction cost inflation on an annual basis to aid in short and long-term planning for resource allocation to the construction program. Construction contractors can adjust volatile commodities, like asphalt, if the market price varies from the bid price by a specified percentage. This eliminates the need to adjust bids to hedge for price volatility. ADOT monitors construction and materials prices so that programming adjustments can be made to adapt to volatile prices. ADOT maintains a contingency fund that can be used to adjust for short-term price volatility.

5.3.2.11 Competing Spending Priorities

The State and the Federal government have numerous spending priorities which can cause transportation funding to be diverted to other purposes. These diversions can have a significant impact on a transportation agency's ability to maintain its assets. In fact, during the Great Recession reduced funding due to diversions contributed to an overall deterioration of ADOT's bridge and pavement assets. ADOT monitors changes in funding and communicates the impacts to the Governor and the Legislature.

5.3.2.12 Flood Damage Including Scour

Scour around bridge piers can lead to bridge failure if not addressed. In 1992, as a result of bridges lost due to scour during the 1970s and 1980s, a statewide scour evaluation work plan was developed for all bridges located over waterways. Inspections during the 1990s identified several hundred bridges as at high risk of scour. Many of these bridges were constructed before 1980 when the adoption of more stringent design criteria improved scour resistance. In the mid-1990s, a subprogram was set up to implement scour counter measures for high-risk bridges. On-going inspections since then have identified additional bridges at high risk for scour.

Currently, there are about 100 ADOT bridges (including some on the NHS) that fit in this category. The scour counter measures subprogram is still in place and new improvement projects are developed yearly. Culverts are subject to blockage, which can lead to flooding or washout of the roadway. Steel pipe culverts can corrode, affecting the structural integrity of the pipe. A significant number of culverts in the state are affected by these conditions. The FY 2016 Level of Service evaluation rated drainage structure conditions at a C+. To address this issue, $4.3 million was approved by the Legislature in the FY 2018 State budget to begin repair of these culverts. The program will begin by repairing the most severely affected culverts starting with 75% blockage and/or 50% rusting. ADOT's intention is to continue the program in future years to repair the remaining drainage structures.

ADOT operates 72 storm water pump stations on 275 miles of urban freeway in the Phoenix Metropolitan area. The ability of these facilities to adequately remove storm water from the freeways is critical to prevent flooding. Construction of the pump station system began in 1964 and pump stations have been incrementally added over time. Per an *ADOT Phoenix District Pump Station Evaluation* [8]:

> *"The incremental construction of the system, over the long-time period, has resulted in a system that lacks uniformity, standardization, and a long-term maintenance and/or replacement plan. This has led to maintenance concerns and issues that have compounded over time and now challenge the System Maintenance Section's maintenance staff resources to adequately maintain and repair the facilities."*

Furthermore, many of the older pump stations weren't designed to handle the additional storm water generated by the addition of travel lanes to freeways that has occurred.

ADOT does not have a dedicated funding source to upgrade and repair aging pump stations; thus, the focus has become how to most efficiently manage the pump station inventory. Currently, ADOT pump operators use an Excel spreadsheet to assess "criticality" of pumping stations which relies entirely on manual inputs of current status data and a custom percent uptime metric that describes overall system status. The current Excel tool is critical for making day-to-day decisions about where to prioritize resources. However, it provides no predictive capabilities for how the hardware might perform into the future and where to prioritize preventative maintenance and capital improvements.

ADOT is in the process of developing a dynamic reliability analysis decision-support tool to provide real-time information to operators considering hardware and environmental conditions to prioritize maintenance and rehabilitation. The tool will be based on state-of-the-art reliability methods. The tool will be positioned to reduce costs associated with maintenance and rehabilitation of pumps while increasing reliability by identifying which hardware should be serviced ahead of failure."[1]

5.3.2.13 Collision Damage to Bridges

Vehicle collisions with bridges happen several times per year. Occasionally, these collisions result in partial or complete bridge closures, sometimes affecting both the crossroad and mainline. Since many highways in Arizona lack redundant routes, these closures can cause lengthy delays. ADOT's bridge clearances are clearly posted and almost all the collisions are the result of driver error. ADOT mitigates this by seeking reimbursement from at fault third parties for damage to bridges subject to collision.

Regularly updated emergency detour plans are an important way to mitigate the impacts of road closures. Some of ADOT's emergency detour plans are outdated and will need to be systematically updated. Raising low bridges also could reduce the opportunity for collisions and is considered in the project scoping process.

5.3.2.14 Non-permitted Overweight Load Related Damage

The maximum weight limit for trucks (five axles or greater) in Arizona is 80,000 pounds without a special permit. Per an ADOT research study *[9]*:

> *"The overloaded truck, whether legal or illegal, contributes to premature pavement fatigue. Pavement deterioration accelerates with axle weight, the number of axle loadings and the spacing within axle groups. The axle loads and spacing on trucks also affect the design and fatigue life of bridges. Steel bridges and pre-stressed concrete spans, if overloaded, are susceptible to fatigue."*

Because fatigue from the repeated stress of overweight trucks can shorten the life of bridges and pavements, it is important to ensure that truckers comply with the weight limit. There are numerous opportunities for trucks to "run heavy" without proper permits and a low chance of being identified when:

- Port of entry facilities are closed.
- Trucks enter the state where there are no ports of entry.
- Inspection queues at ports get too long and trucks are waved past.
- Trucks "run" by ports without stopping for inspection.

1 *(Pumping Station Reliability Proposal; Mikhail Chester, Ph.D., Emily Bondank; Arizona State University; October 15, 2018)*

- Trucks unload some of the cargo at the border to cross separately, such as sometimes occurs with car trailers.
- Truck trips originate within the state.

A cost-effective way to detect unpermitted overweight trucks is the installation of weigh-in-motion (WIM) stations in the roadway. WIM stations measure the weight of a truck as it passes over a device in the pavement. Unlike ports of entry, WIM stations operate 24 hours a day, every day of the year. Data from WIM stations indicate that about 7 to 10 percent of the trucks on Arizona highways run overweight. In recent years, ADOT expanded and upgraded WIM stations with the latest law enforcement grade Piezo-quartz sensors for improved accuracy. ADOT operated 18 WIM stations in 2017. ADOT constructed 14 new quartz WIMs at 10 sites in fiscal year 2018.

The weight measured with the WIM station is confirmed on a static scale before a citation is issued. ADOT also operates static scales at three rest areas (Sacaton westbound, McGuireville southbound, and Canoa Ranch northbound) and portable scales that can be placed at other rest areas to detect overweight vehicles that bypassed the port of entry or originate in Arizona.

5.3.2.15 Lack of Redundant Routes if an Asset Fails

Due to geographical constraints, Arizona has many highways without efficient alternatives to re-route traffic should an asset failure require a closure. Thus, it is critical that these highways are maintained in good condition to minimize closures and impacts to travelers and freight. ADOT has long considered the importance of a route/asset in the prioritization of asset preservation, rehabilitation and reconstruction projects. ADOT accounts for the relative importance of a route/asset by considering the following network strategic factors when prioritizing projects:

- Number of lanes
- Functional classification of the route
- Current average annual daily traffic volume
- Future average annual daily traffic volume
- Percent truck traffic
- Route on the National Truck Network
- Existence of a parallel bridge
- Defense highway
- Designated emergency route
- Detour length
- Border crossing affected
- Historical significance

5.3.2.16 Inadequate Maintenance Budget

There are more than 250 maintenance activities needed on a routine basis to keep the 21,000+ lane-miles of Arizona highways open for business. The maintenance area most susceptible to inadequate funding is the pavement surface treatment program. Deteriorated roadway surfaces require higher-cost restoration work to re-establish the structural integrity and capacity of the pavement system. This rehabilitation work includes expensive pavement overlays and milling and replacement of existing pavements. These expensive treatments could be reduced if low cost surface treatments are applied at strategic intervals. For example, the cost of surface treatments like a flush coat is $3,000 per lane mile and a chip seal is $36,000 per lane mile. In comparison, the rehabilitation of roadway surfaces costs ADOT $300,000 to $360,000 for one lane mile on non-interstate and interstate, respectively. The life cycle planning analysis and investment strategies selected describe ADOT's approach to reduce long-term costs through an increased use of preservation treatments.

The average funding level for pavement surface treatments was about $15 million per year for the last five years, allowing the surface treatment of just 300 to 400 travel lane miles, which is less than 2% of the entire system. This level of investment is insufficient to keep pavements on the highway system from deteriorating to the point when expensive rehabilitation and reconstruction are the only options. To prevent this, funding is needed to apply preventative surface treatments to about 14% of lane miles, at an estimated cost of $36,100,000 per year. That recommended amount of spending authority was approved in the FY 2020 budget.

5.4 Facilities Repeatedly Damaged by Emergency Events

MAP-21 regulations require that state DOTs "conduct statewide evaluations to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events." The evaluations must include repeated emergency events on any road, highway or bridge that occurred January 1, 1997, or later. The statewide evaluation for all NHS roads, highways and bridges must have been completed by November 23, 2018. Beginning on November 23, 2020, a state DOT must prepare evaluations covering the affected portion of all other roads, highways and bridges "prior to including any project relating to such facility in its STIP" (23 Code of Federal Regulations Part 667). The statewide evaluation must be updated every four years. State DOTs must consider the results of the evaluations when developing a TAMP and during preparation of the STIP.

ADOT identified four locations that received emergency funding on at least two occasions for similar events, as listed below.

- State Route 87 near Milepost 224. Landslide and related slope stability issues (NHS).
- State Route 89A; Mileposts 375 to 399. Erosion due to storm events.
- State Route 71; Milepost 86. Scour and embankment repair.
- Salome Road, Centennial Bridge (La Paz County). Flow over the roadway.

5.4.1 Summary of Evaluation for State Route 87 near Milepost 224

ADOT prepared an evaluation of the State Route (SR) 87 landslide and related slope stability issues which is referenced in Appendix A.

Since 2005 there have been five emergency events on SR 87 near Milepost (MP) 224:

- Heavy rains in 2004 and 2005 caused the cut slopes and soil nail walls between MP 224 and MP 226 to begin to experience localized failures. Project ER-087-224, TRACS No. H6745 01C ($2.4 Million) removed several of the failed soil nail walls and regraded the cut slopes to reduce the steepness of the slope grades. The excavated material was utilized to buttress an existing 100+ foot embankment with 1.5:1 (H:V) slope rate. This embankment was exhibiting signs of failure with tension cracking affecting the pavement.

- Project ER-087-B-NFA, TRACS No. H7035 01C ($5.1 Million) began construction in March, 2008. The project removed additional soil nail walls that had failed, flattened the existing cut slopes, and continued the embankment buttress stabilization. During the early portion of the project, and after a period of heavy precipitation events, a landslide at MP 224.3 closed the highway for approximately 1 week. Additional excavation, soil-nail wall removal, and embankment construction was added to the project. A total of 89 soldier piles (30” diameter x 43’ deep) and 9 drilled shafts (48” diameter x 65’ deep) were also added to the project. A total of approximately 186,300 cubic yards (CY) of material was excavated, and utilized to improve stability of the 100+ foot embankment.
- Project ER-087-B(201)A, TRACS No. H7700 01C ($1.8 Million), was constructed in 2009 as a result of the geotechnical investigation and monitoring. The drilled shafts and soldier piles previously installed in 2008 as emergency mitigation measures were being displaced and bent by a continued slow slide movement. A total of 26 drilled shaft shear piles (66” diameter x 73’ deep) were installed in the landslide, and approximately 75,000 CY of material was excavated and used to construct an additional Northbound embankment buttress near MP 226 in anticipation of a possible alignment shift. A rock buttress was placed behind the Southbound barrier between MP 224.3 and MP 224.4 to aid in stabilizing the local slide at that location. A separate rock buttress was placed behind the Southbound barrier from MP 224.0 to MP 224.1 to stabilize a partially failed soil nail wall. The 12-foot diameter multi-plate pipe in Slate Creek (MP 226) was extended.
- Heavy rains in January 2010 resulted in a change in the slide conditions and the slide began to show an increase in the rate of movement due to increased pore water pressure heads in the perched groundwater trapped in the landslide near MP 224.3. To save the shear piles, Project ER-087-B(208)A, TRACS No. 8175 01C, excavated approximately 62,000 CY above the shear piles, and installed a series of horizontal slope drains to reduce the groundwater in the slopes adjacent to the roadway.
- Project ER-087-B(207)A, TRACS No. H8072 01C ($1.5 Million) was constructed in February of 2012. This project removed the Northbound upper tiered wall and a portion of the damaged Northbound lower wall near MP 224.2. An estimated 124,000 CY of material were excavated and used to construct additional Northbound embankment buttress near MP 226.

Stability failure of the slopes is attributed to global stability failure due to low shear strength soil and periods of high rainfall. Saturation of the low plasticity silt and clay deposits behind and under the earth retaining structures creates lateral forces and weakens the shear strength of the soils. Saturation of the site soils is increased due to the fractured, inconsistent depositional history of the site soils due to historic landslides. Fissures and soil physical property changes within the soil mass creates zones of water infiltration and retention. Retention of water within the soil mass creates excessive lateral forces which have caused catastrophic failure of the slopes during and after periods of heavy precipitation.

Heavy rainfall and catastrophic failure of the slopes have shown a strong cause and effect relationship. Piezometer instrumentation has documented significant increases in groundwater elevation following periods of heavy rainfall. Loss of shear strength of the saturated soil combined with lateral forces due to saturation is the root cause of the slope failures. SR 87 is a major commerce corridor between Phoenix and Payson. Mobility impacts to SR 87 are probable if slope stability failures occur. Saturation of site soils must be mitigated to limit risk of future slope stability failures.

Mitigation measures to date have included slope flattening, shear piles, lateral drains, rock buttresses, and drainage channeling. Installation of shear piles has proven ineffective due to inability to control large lateral forces due to saturated soils. Control of the subsurface water content through lateral drains is the most cost-effective mitigation strategy. Additional strategies to stabilize the near surface with native plant vegetation should be investigated. Initial layback of slopes where wall failures have occurred are necessary to provide a slope angle that is suitable for vegetation establishment and erosion control. Slope flattening should be minimized to limit impacts to right of way.

Rock buttressing provides stability and a highly permeable pathway to remove water from the toe of slope. Importation of angular rock and disposal of displaced soil is expensive. Surface drainage control provides low cost and benefits the management of slope erosion. Control of surface water also reduces the volume of water that may infiltrate the site soils. Lining of drainage channels with an impermeable barrier may be an effective strategy.

Continued monitoring of the area is recommended. Installed instrumentation and lateral drainage systems should be maintained. The following two slopes have been identified for immediate mitigation:

- Northbound slope from station 2804+00 to station 2810+00 has developed surficial indications of a slope failure following heavy rains from the remnants of hurricane Rosa.
- The South Bound slope from station 2801+00 to 2806+00 upper tier was removed in a previous project. Since the upper tier removal, the lower tier has begun failing. Heavy erosion is also occurring above the lower tier. The slope is more than 100 feet tall and will continue to fail.

ADOT will perform an annual review, in January, to determine if new eligible emergency events have occurred during the previous calendar year and determine if those events are repeated. If so, ADOT will coordinate the preparation of the appropriate Part 667 documentation with the FHWA Arizona Division office. If not, the Division office asset management liaison will be notified by e-mail that there were no repeated emergency events during the previous year.

Section 6
Financial Plan

6.1 Overview

This section discusses ADOT's financial planning over the next ten years in alignment with the Federally-required financial planning approach outlined in 23 CFR 515.7. This financial plan summarizes an estimated valuation for ADOT's pavement and bridge assets, historic funding sources and uses, and an estimate of projected funding sources that can be used for asset management and other preservation activities.

6.2 Asset Valuation

Under the Governmental Accounting Standards Board Statement No. 34, *Basic Financial Statements – and Management's Discussion and Analysis – for State and Local Governments (GASB 34)*, as amended, ADOT reports asset valuations of its roads and bridges using the "modified approach". This approach allows asset values to be maintained without depreciation as long as the following required actions are undertaken:

- Maintain an asset management system that includes an up to date inventory of eligible infrastructure assets.
- Perform condition assessments of eligible assets and summarize the results using a measurement scale.
- Estimate each year the annual amount to maintain and preserve the assets at the condition level established and disclosed by ADOT.
- Document that assets are being preserved approximately at or above the established condition level.

The undepreciated value of ADOT's transportation infrastructure as of June 30, 2018, is provided in Table 26 (SHS) and Table 27 (NHS).

Table 26 — Undepreciated Value of SHS* Transportation Infrastructure (YOE dollars in billions)**

Pavement	Bridges	Land	Construction in Progress	Total
$13.611	$2.691	$3.462	$2.372	$22.136

**SHS includes state-owned portions of the NHS*
***YOE: Year of Expenditure*
NOTE: Valuation method is pursuant to Governmental Accounting Standards Board Statement 34 (GASB 34).

Table 27 — Undepreciated Value of NHS Transportation Infrastructure (YOE* dollars in billions)

Pavement	Bridges	Land	Construction in Progress	Total
$10.480	$2.072	$3.454	$1.826	$17.832

**YOE: Year of Expenditure*
NOTE: Valuation method is pursuant to Governmental Accounting Standards Board Statement 34 (GASB 34).

ADOT recognizes that the "modified approach" does not reflect the replacement costs of infrastructure assets. As an alternative approach, ADOT also estimates asset value based on current replacements costs. Asset valuation results based on the replacement cost are presented in Table 28. Unit replacement costs as of March 2019 were used to estimate the replacement value of pavement and bridges.

Table 28 — Estimated Replacement Cost for Pavement and Bridges

Bridge System	2018 Deck Area (ft^2) *	Unit Replacement Cost	Replacement Estimate
NHS (State only)	31,426,851	$450 per ft^2	$14.142 billion
ADOT Non-NHS	12,324,010	$450 per ft^2	$5.558 billion
Subtotal			**$19.700 billion**

Pavement System	2018 Lane Miles*	Unit Replacement Cost	Replacement Estimate
INTERSTATE			
Asphalt	4790	$1,062,000/lane mile	$5.087 billion
Composite/Concrete	615	$1,145,000/lane mile	$0.704 billion
NON-INTERSTATE NHS (STATE ONLY)			
Asphalt	5098	$819,000/lane mile	$4.175 billion
Composite/Concrete	1732	$1,145,000/lane mile	$1.983 billion
NON-NHS			
Asphalt (Tier 1) **	7906	$742,000/lane mile	$5.866 billion
Asphalt (Tier 2)	570	$636,000/lane mile	$0.363 billion
Composite/Concrete	593	$1,145,000/lane mile	$0.679 billion
Frontage Roads	997	$636,000/lane mile	$0.634 billion
Asphalt Shoulder***	7874	$636,000/lane mile	$5.008 billion
Subtotal			**$24.499 billion**
Total Estimated ADOT Bridge and Pavement Replacement Costs			**$44.195 billion**

**Estimated March 2019 for planning purposes - includes auxiliary lanes, passing lanes and ramps. Right-of-way costs not included.*
***Tier 1 & 2 -Asphalt pavements are designed to withstand different traffic volumes; more traffic requires stronger, costlier pavement.*
****Shoulder area converted to 12-foot lane miles.*

While acknowledging the value of pavement and bridge assets by their replacement cost (replacing to new condition), ADOT generally prefers to maintain the undepreciated cost method for asset valuation given that the required actions listed above are undertaken. In addition, reporting infrastructure assets under Generally Accepted Accounting Principles requires ADOT to report all asset at historical cost. The cost to maintain this value of the infrastructure is presented in Section 7 of this TAMP.

6.3 Funding Plan

The long-range strategic direction outlined as part of the *What Moves You Arizona (WMYA) 2040 Statewide Long-Range Transportation Plan* includes three programs: preservation, modernization, and expansion.

- **Preservation.** Spending to maintain pavements in good condition and maintain bridges in a state of good repair. This should not be confused with the preservation work type which describes specific treatments that extend asset service life (e.g. chip seals, deck overlays, etc.) Preservation treatments can be included in both modernization and expansion projects as well.
- **Modernization.** Non-capacity spending that improves safety and operations of the existing SHS through activities such as adding shoulders and implementing smart road technologies.
- **Expansion.** Improvements that add capacity to the SHS through new roads, adding lanes to existing highways and constructing new interchanges.

WMYA 2040 envisioned a shift in ADOT investments in highways from physical expansion of highways to preservation of existing assets. In WMYA 2040, ADOT developed “Recommended Investment Choices” (RIC) that were data-driven and also incorporated input from stakeholders and the public. The process centered on developing a series of “Alternative Investment Choices” (AICs) that represented different perspectives on how ADOT’s resources could or should be allocated in the future. The AICs, in effect, served as data points to inform development of the final RIC. More information the development of the RIC can be found in *Recommended Investment Choice (RIC) Development*[2] in Appendix A.

Table 29 shows the final 25-year statewide highway capital needs using the RIC development process and included in the WMYA 2040 Plan. In contrast, 25-year revenue estimates developed by ADOT’s Office of Financial Management Services indicates that $23 billion in constant dollars will be available for highway capital spending. On an annual basis, this equates to average revenue of $923 million, which was used as the available funding estimate for developing the Statewide and regional RICs. More information on the capital needs, revenue forecast and gap can be found in *Existing Conditions, Deficiencies and Future Needs*[3] and *Revenue Forecast and Gap Analysis*[4] in Appendix A.

Figure 25 shows the resulting annual average allocations by investment area (expansion, modernization, preservation) which corresponds to the final RIC.

2 *Arizona Long Range Transportation Plan Update. Recommended Investment Choice (RIC) Development. October 2017.*

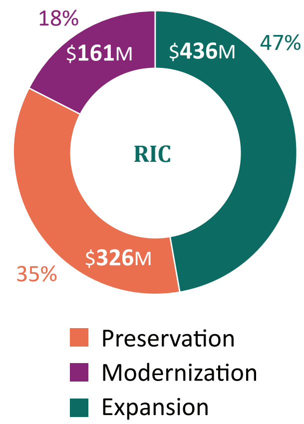
3 *Arizona Long Range Transportation Plan Update. Existing Conditions, Deficiencies and Future Needs. February 2017.*

4 *Arizona Long Range Transportation Plan Update. Revenue Forecast and Gap Analysis. April 2017.*

Table 29 — 25-Year Statewide Capital Needs

Investment Category	25-Year Need ($Billions)
Preservation	9,236
Pavement Preservation	*7,902*
Bridge Preservation	*1,334*
Modernization	9,862
Expansion	34,054
Total	53,152

Figure 25 — Recommended Investment Choices Average Annual Allocation



WMYA 2040 recommended investing $326 million annually for bridge and pavement preservation, about 30% more than was allocated in the previous program (WMYA 2035). The additional funding was made available by phasing out expansion projects in greater Arizona, outside the Maricopa Association of Governments (MAG) and Pima Association of Governments (PAG) areas areas. The number of expansion projects in greater Arizona is decreasing on a year by year basis and is projected to be phased out completely by the end of 2024.

The RIC is based on the WMYA 2040 25-year planning horizon; therefore, it is intended to be an average of annual investments throughout the planning horizon. As a result of Federal requirements (23 USC 150) associated with development of “state of good repair” performance metrics and targets, ADOT will continually monitor the impact of preservation investments on infrastructure condition. This continual monitoring of system performance and progress moving towards pavement and bridge condition targets will lead to on-going annual discussions related to the need for pavement and bridge preservation investment level changes.

In addition to monitoring pavement and bridge condition on an annual basis, ADOT is required to update the Statewide Long-Range Transportation Plan every five years. During future updates a data-driven analysis and revisiting of the RIC will occur. Due to a general tendency of the agency to focus on expansion projects in the past as a result of rapidly growing population, and unique economic factors including the Great Recession, ADOT is in the process of playing catch-up with regards to maintenance activities, therefore increased investments in preservation activities are seen for the foreseeable future.

6.4 Funding Sources & Projections

ADOT relies on Federal, state, and regional sources of funding to finance asset preservation. Local governments also have funding that is used for asset preservation on the NHS. Primary funding sources are listed below:

1. **Federal Aid Highway Program (FAHP)**

2. **State Funding - Highway User Revenue Funds (HURF)**

    - Motor Vehicle Fuel Tax
    - Motor Vehicle Registration Fee
    - Motor Carrier Tax
    - Motor Vehicle Operator' License Fees and Miscellaneous Fees
    - Motor Vehicle License Tax

3. **Regional Funding – such as the Regional Area Road Fund (RARF; restricted to use only in Maricopa County) and Regional Transportation Authority (RTA) funding in Pima County**

4. **Local Funding**

6.4.1 Historical Funding by Source

Figure 26 shows the funding available for highway investments from the Federal, state and local funding sources described above. Total funding for FY 2018 (the most recently completed state fiscal year) from all four funding types was approximately $1.9 billion. As shown, funds from the State Highway Fund and Federal Aid Programs provided 76% of the available funding for highway investment.

Figure 26 — FY 2018 Highway Available Funds by Funding Type

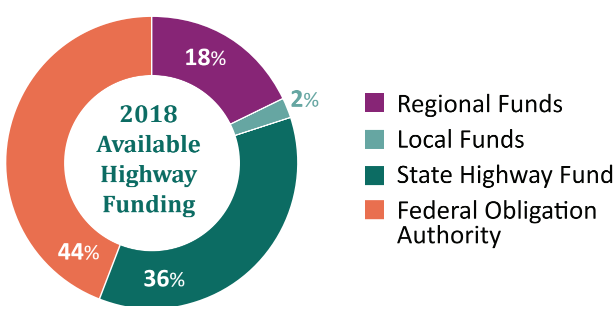


Table 30 presents the historical funding by type for highway investment. Note that the State Highway Fund is used for capital and operating purposes, and the MAG funding shown is 66.7% of the regional excise tax. Between 2009 and 2018, funding averaged $1.57 billion per year with total available funding for the period of $15.67 billion. Funding has generally increased since the end of the "Great Recession", and is anticipated to increase for the foreseeable future as the Arizona population increases and the economy continues to expand.

Table 30 — Historical Revenues by Funding Type

Fund Types and Sources	Actual Revenues (Millions $)									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
State Highway Fund	506	501	504	370	524	538	566	589	611	625
Federal Obligation Authority	691	707	713	700	685	708	714	767	758	696
Regional Funds										
MAG (RARF)	219	199	206	216	228	244	255	265	276	293
PAG (RTA)	25	62	41	57	55	53	59	80	80	23
Local Funds	26	26	26	26	26	26	26	26	26	26
TOTAL	**1467**	**1495**	**1490**	**1369**	**1518**	**1569**	**1620**	**1727**	**1751**	**1663**

6.4.2 Federal Funding

ADOT's primary source of Federal funding comes from the FAHP administered by FHWA, primarily funded through the Federal Highway Trust Fund. Funding under the FAHP is provided to states through a multi-step funding cycle that includes: 1) *multi-year authorization* by Congress of the funding for various highway programs; 2) *apportionment and allocation* of funds to the states each FFY according to statutory formulas or, for some funding categories through administrative action; 3) *obligation* of funds, which is the Federal government's legal commitment (or promise) to pay or reimburse states for the Federal share of a project's eligible costs; 4) *appropriations* by Congress specifying the amount of funds available for the year to liquidate obligations; 5) *program implementation* which covers the programming and authorization phases; and 6) *reimbursement* by the Federal government of the eligible project costs.

The current multi-year program, Fixing America's Surface Transportation (FAST) Act, was signed into law on December 4, 2015, and provides funding for FFY 2016 through FFY 2020. The FAST ACT establishes apportionment formulas using such data as highway system mileage, lane miles, traffic volumes, and estimated Federal fuel tax contributions.

The apportionments are provided to states in various categories which define eligible types of investment, the largest of which are the National Highway Performance Program (NHPP) and Surface Transportation Block Grant Program (STBGP). Eligible uses in these categories include:

- **Surface Transportation Block Grant Program (STBGP).** This is the most flexible of Federal transportation funds and may be used for a wide variety of highway, transit, or street projects, including pavement and bridge maintenance activities.
- **National Highway Performance Program (NHPP).** Under the FAST Act, this category combined the Interstate Maintenance Program, the National Highway System, and the Highway Bridge Replacement and Bridge Rehabilitation Program. NHPP is the primary Federal funding source utilized for pavement and bridge preservation, but can only be used for routes on the National Highway System.

Only NHPP and STBGP funds are eligible to be used for bridge and pavement preservation. Table 31 shows ADOT Federal funding for the remainder of the FAST Act. For 2020 and beyond, funding levels are held constant, conservatively assuming no growth, to estimate Federal aid beyond the FAST Act. This table shows the estimated amount of funds eligible to be used by ADOT for asset management, although these funds also may be used for other transportation purposes.

Table 31 — Estimated Federal Aid (dollars in millions)

Federal Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Federal Obligation Authority	701	750	750	750	750	750	750	750	750	750
NHPP	417	424	424	424	424	424	424	424	424	424
STBGP	101	104	104	104	104	104	104	104	104	104
Total Eligible Amount	518	528	528	528	528	528	528	528	528	528

The FAHP is a reimbursement program. Once projects are authorized in advance by FHWA and Federal funds are obligated, the Federal government reimburses states for costs as they are incurred. With few exceptions, Federal reimbursements must be matched with state or local funds. For most projects in Arizona, the Federal share is 94.3%, and the state/local share is 5.7%.

6.4.3 State Funding

The state of Arizona taxes motor fuels and collects a variety of fees and charges relating to the registration and operation of motor vehicles on the public highways of the state. These collections include gasoline and use-fuel taxes, motor-carrier taxes, vehicle-license taxes, motor vehicle registration fees and other miscellaneous fees. These revenues are deposited in the Highway User Revenue Fund (HURF) and are then distributed to the cities, towns and counties, and the State Highway Fund and for other transportation related purposes. Information regarding the forecasting of HURF revenues follows, along with actual revenues for state FY 2018 and a 10-year history.

Since 1986, ADOT has estimated HURF revenues using a comprehensive regression-based econometric model. To deal with uncertainty regarding this estimate, ADOT introduced its risk analysis process in 1992. This process relies upon probability analysis and the independent evaluation of the model's variables by an expert panel of economists. This results in a series of forecasts with specified probabilities of occurrence, rather than a single or "best guess" estimate. More information about the HURF forecast can found in *Arizona Highway User Revenue Fund Forecasting Process & Results FY 2019-2028* in **Appendix A**.

ADOT's official forecast for FY 2019-2028 HURF amounts to $17,355 million with a compound growth rate of 3.2%. The Official Forecast incorporates the 50% confidence interval growth rates produced by the Risk Analysis Process model for each year of the forecast except for FY 2019. The FY 2019 forecast of $1,490 million was developed in July 2018 by ADOT staff using time-series techniques, historical and projected growth rates, and recent legislative changes. **Table 32** presents the estimated HURF funds by category for FY 2019-2028.

Table 32 — HURF Official Revenue Forecast with Category Details – FY 2019 - 2028

	Estimated Total Funds (in millions)									
Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Gasoline Tax	537.9	545.7	556.1	565.6	574.1	583.4	592.1	600.7	609.5	618.3
Use Fuel Tax	202.3	208.8	216.9	224.5	231.6	238.2	245.0	251.7	258.4	264.8
Motor Carrier Fee	43.3	45.6	47.1	48.4	49.8	51.2	52.6	54.1	55.6	57.1
Vehicle License Tax	466.1	499.8	529.6	557.8	586.4	615.3	645.6	676.7	708.9	743.5
Registration	183.0	187.1	191.5	195.6	199.8	204.0	208.4	212.9	217.5	222.1
Other	57.6	61.0	62.9	64.8	66.5	68.4	70.2	72.0	73.9	75.7
Total HURF	**1490.2**	**1548.0**	**1604.1**	**1656.7**	**1708.2**	**1760.5**	**1813.9**	**1868.1**	**1923.8**	**1981.5**
State Highway Fund	**672.1**	**750.4**	**788.6**	**814.1**	**838.9**	**864.2**	**890.1**	**916.3**	**943.3**	**971.3**

SOURCE: ARIZONA HIGHWAY USER REVENUE FUND FORECASTING PROCESS & RESULTS FY 2019-2028.

Figure 27 depicts HURF revenues by source for FY 2018, the most recently completed state fiscal year. As shown, fuel tax and VLT comprised 81% of total HURF revenues.

Figure 27 — FY 2018 HURF Revenue by Source

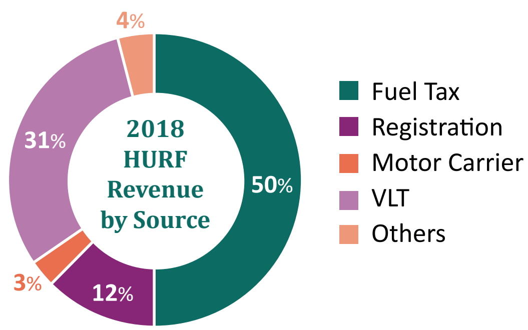


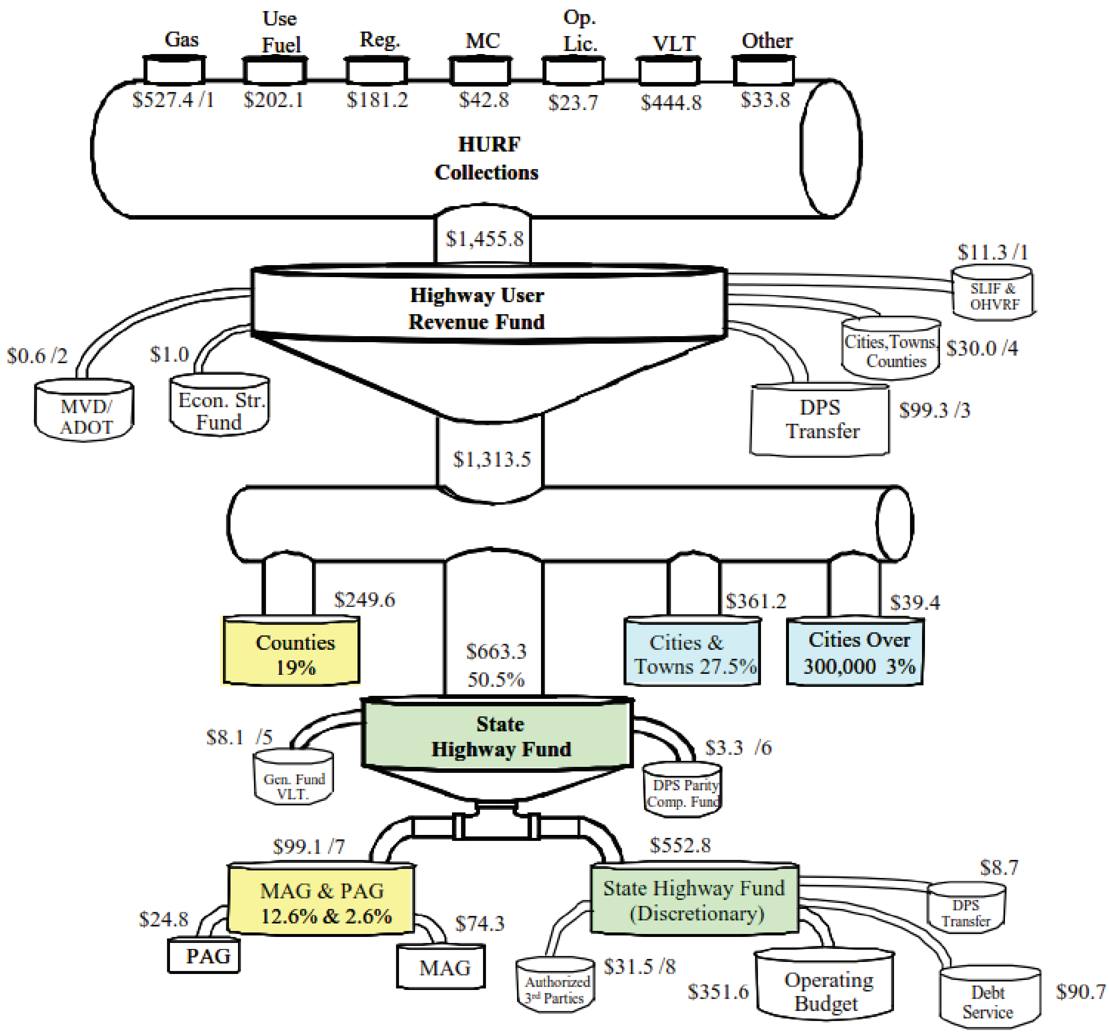
Table 33 shows historical HURF revenues by source for the 10-year period of state FY 2009 through FY 2018.

Table 33 — Actual Highway User Revenue Fund Revenues by Source (FY 2009-2018, $Millions)

Year	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
Fuel Tax	631	627	635	635	631	634	655	688	706	729
Registration	168	152	156	158	158	164	169	174	178	181
Motor Carrier	40	36	36	37	37	39	40	41	42	43
Vehicle License Tax	357	330	322	321	327	349	370	396	422	445
Others	52	50	56	59	57	56	57	58	58	58
Total	**1248**	**1195**	**1205**	**1210**	**1210**	**1242**	**1291**	**1357**	**1406**	**1456**

HURF revenues are allocated and distributed by statute and through annual budget legislation. Figure 28 shows actual HURF revenues and distributions for FY 2018, in which funding from all sources was $1,455.8 million. Allocations and distributions from HURF are made to various stakeholders, such as the Department of Public Safety, Motor Vehicles Division, State Highway Fund, and cities, towns and counties. The State Highway Fund is further allocated between Arizona's two largest metropolitan planning organizations, ADOT and other transfers.

Figure 28 — FY 2018 HURF Revenue Distribution Flow (dollars in millions)



NOTES:
**See notes in FY 2018 HURF Actual Revenue Distribution Flow.*
VLT – Vehicle License Tax, Division, DPS – Department of Public Safety

SOURCE: ADOT FINANCIAL MANAGEMENT SERVICES

After such allocations and distributions are made, projected amount of State Highway Funds available to be programmed for transportation projects by ADOT is shown in Table 34.

Table 34 — Forecasted State Funding Available for Transportation Purposes – FY 2019 - 2028

State Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Funding ($Millions)	49	115	18	75	213	170	250	247	257	279

6.4.4 Regional and Local Funding

Several counties in the state collect taxes that support regional transportation needs. They include Maricopa, Pima, Pina, and Gila counties. Of these, Maricopa and Pima, which have the largest contributions to regional transportation needs, are described below.

6.4.4.1 Maricopa County

In November 2004, voters in Maricopa County approved a county excise tax for transportation purposes which primarily include expansion and modernization but may include preservation projects on the NHS although this is rare. These tax revenues are collected by the Arizona County Regional Area Road Fund (RARF). In 2004, Maricopa County voters approved a ½ cent sales tax that sunsets after 20 years and, thus, is set to expire on December 31, 2025 unless extended. If the sales tax is not extended by the voters of Maricopa County, funding for roadway projects, pavement, and bridge projects in the Phoenix region could drop dramatically, creating an even larger funding gap for preservation activities. The gross receipts from the tax are collected by the Arizona Department of Revenue and split 66.7% to the Maricopa County RARF and 33.3% to the Public Transportation Fund (PTF).

Like HURF revenue estimation approaches, since 1986, ADOT has used a comprehensive regression-based econometric model to estimate Transportation Excise Tax revenues in Maricopa County. These revenues, which flow into the RARF, are the major funding source for the Maricopa County Freeway Program. To deal with uncertainty regarding this estimate, ADOT introduced its risk analysis process in 1992. This process relies upon probability analysis and the independent evaluation of the model's variables by an expert panel of economists. This results in a series of forecasts with specified probabilities of occurrence, rather than a single or "best guess" estimate. More information about the RARF forecast can found in *Maricopa County Transportation Excise Tax Forecasting Process & Results* in **Appendix A**.

ADOT's official forecast for FY 2019-2026 RARF revenue amounts to $4,215.5 million with a compound growth rate of 5.1%. The Official Forecast result incorporates the 50% confidence interval growth rates produced by the Risk Analysis Process model for each year of the forecast except for FY 2019. The FY 2019 forecast of $466.4 million was developed by ADOT staff independently of the econometric model using time series techniques, historical growth rates, projected growth rates and recent legislative changes. **Table 35** presents the estimated RARF funds (excluding the Public Transportation Fund) showing how they are expected to be subdivided from 2019 to 2026.

Table 35 — RARF available for Arterial Street and Freeway transportation projects (dollars in millions)

REGIONAL AREA ROAD FUND (RARF)			
Fiscal Year	**Freeways**	**Arterial Streets**	**Total**
2019	$262.1	$49.0	$311.10
2020	$276.6	$51.6	$328.20
2021	$291.9	$54.5	$346.40
2022	$306.8	$57.3	$364.10
2023	$322.9	$60.3	$383.20
2024	$338.1	$63.2	$401.30
2025	$354.7	$66.3	$421.00
2026	$216.0	$40.4	$256.40
Totals	**$2,369.1**	**$442.6**	**$2,811.70**

6.4.4.2 Pima County

In Pima County, a $2.1 billion Regional Transportation Authority (RTA) plan was approved by Pima County voters on May 16, 2006. At the same time, voters approved a transaction privilege tax, or excise tax, to fund the 20-year plan. The RTA is managed by PAG.

The half-cent sales tax collection began on July 1, 2006, and the tax is collected from the state-established RTA special taxing district within Pima County to deliver RTA projects. The Plan will be implemented through June 30, 2026. Some of the projects will be funded with RTA funds only, and other projects will be supplemented by regional funding. The 2006 RTA plan approved by voters and developed by a 35-member citizen advisory committee, public/private technical management committee and extensive public input includes a Roadway Improvement Element consisting of $1.2 billion in RTA funding, and $334 million in Federal and local funds allocated to expanding, modernizing, and preserving roadways. The RTA funding allocated to roadway projects over the next ten years is summarized in Table 36.

Table 36 — Programmed RTA Funds Allocated to Roadway Projects

($ Millions)	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY2026	FY 2027
RTA	79*	64	35	35	37	37	34	20	4

**PAG projects $44,000,000 of FY 2019 funding allocated for roadway projects will be reprogrammed to future years.*

Regional funds from MAG, PAG (RARF and RTA, respectively) and other entities have generally been used to fund expansion projects (as opposed to preservation) pursuant to the enabling language governing such funds. As a result, preservation projects in these regions are typically done with Federal, State and Local funds. Future iterations of the TAMP will provide greater detail on the use of Regional funds specifically for bridge and pavement preservation purposes.

6.4.4.3 Other Jurisdictions

In addition to excise taxes for regional transportation funding in Maricopa, Pima, Gila and Pinal counties, other municipalities and counties throughout Arizona utilize local resources, including taxes, bonds, general funds, HURF, and impact fees to locally fund transportation projects, operations and maintenance, and pavement preservation, and meet various match requirements for local capital projects.

Local government investments in NHS bridge and pavement preservation treatments, rehabilitation and reconstruction are included in Metropolitan Transportation Improvement Plans and TIPs for jurisdictions within MPO boundaries and directly in the STIP for jurisdictions within COG boundaries. These additional contributions generated from local excise taxes, bonds, and CIP funds add funding for pavement and bridge preservation projects throughout Arizona. Contributions reflected in COG and MPO TIPs include local match on federally-funded preservation projects, and funds for projects that are 100% locally- funded.

Local funding for preservation projects is highly variable and difficult to predict due to fluctuating priorities at local levels of government. For FY2018-2022, local programmed amounts for transportation asset preservation projects averaged $26,016,251. Future iterations of the TAMP will provide greater detail on the use of local funds specifically for bridge and pavement preservation purposes.

Table 37 shows the regional and local funding projected for all transportation purposes.

Table 37 — Projected Regional and Local Funding for All Transportation Purposes ($Millions)

State Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Local	26	26	26	26	26	26	26	26	26	26
Federal Obligation Authority	170	155	155	155	155	155	155	155	155	155
Regional (RARF and RTA)	390	392	381	399	420	438	455	276	4	0
State Highway Funds allocated to MAG and PAG Regions	106	111	114	119	129	133	137	141	145	149
Total	**692**	**684**	**676**	**699**	**730**	**752**	**773**	**598**	**330**	**330**

6.4.5 Total Projected Funding Sources

Table 38 presents a summary of the projected revenues for each funding sources described in the previous sections. The table shows that about $19.1 billion in funding would be available for investment in transportation-related projects over the next 10 years.

Table 38 — Projected State Revenue available for Preservation and other Transportation Purposes ($Millions)

ACTUAL TOTAL FUNDS (MILLIONS $)

Fund Types and Sources	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Federal Obligation Authority	701	750	750	750	750	750	750	750	750	750
State Highway Fund	672	710	732	758	828	853	879	905	932	960
Regional Funds	390	392	381	399	420	438	455	276	4	0
MAG (RARF)	311	328	346	364	383	401	421	256	0	0
PAG (RTA)	79	64	35	35	37	37	34	20	4	0
Local Funds	26	26	26	26	26	26	26	26	26	26
TOTAL	**1789**	**1878**	**1889**	**1933**	**2024**	**2067**	**2110**	**1957**	**1712**	**1736**

Regional funds from MAG and PAG are not typically used to fund preservation projects, since these funds are primarily used for expansion projects. Preservation projects in these regions are typically done with Federal, State and Local funds. This funding, shown in Table 38 is available to local and regional entities to be used for pavement and bridge preservation projects on portions of the NHS that they own.

6.4.6 Projected Revenue Available for Preservation

Table 39 shows a 10-year estimate of Federal and State Highway Funds available to be programmed for capital asset preservation, although these funds also may be used for other Arizona State Transportation Board approved priorities.

Table 39 — Projected State Funding available for State Preservation and other Transportation Purposes ($Millions)

State Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
State Highway Fund	49	115	18	75	213	170	250	247	257	279
Federal Obligation Authority	518	528	528	528	528	528	528	528	537	537
Total	**567**	**643**	**546**	**603**	**741**	**698**	**778**	**775**	**794**	**816**

In addition to the capital funding shown in Table 39, ADOT's maintenance budget also provides some funding for non-capital preservation treatment activities. The budget is approved annually by the Arizona Legislature and can be difficult to forecast. The approved FY 2019 maintenance budget included $25.6 million for pavement surface treatments. The approved FY 2020 maintenance budget included $36.142 million for surface treatments. It is anticipated that pavement surface treatment funding will remain at FY 2020 levels in the foreseeable future. These amounts have been added to the available capital funding for pavement and are reflected in the programmed pavement funding in Table 40.

The funding identified in Table 39 may be used for expansion, modernization or preservation. Of that amount, Table 40 reflects the estimated amount expected to be programmed for bridge and pavement preservation Forecasted amounts by specific work types (including initial construction) are discussed with the investment strategies in the next chapter.

Table 40 — Estimated Amounts of Funds available to be programmed for State Bridge and Pavement Preservation ($Millions)

State Fiscal Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
BRIDGE	**115**	**73**	**133**	**84**	**60**	**60**	**85**	**65**	**60**	**60**
NHS	83	53	96	60	43	43	61	47	43	43
Non-NHS	32	20	37	24	17	17	24	18	17	17
PAVEMENT*	**247**	**216**	**152**	**179**	**217**	**205**	**277**	**297**	**297**	**317**
NHS	168	147	103	122	148	139	188	202	202	216
Non-NHS	79	69	49	57	69	66	89	95	95	101
Total	**362**	**289**	**285**	**263**	**277**	**265**	**362**	**362**	**357**	**377**

**Presumes that ADOT will continue to receive $36.5 million annually of maintenance funding for pavements.*

Section 7
Gap Analysis & Investment Strategies

7.1 Overview

FHWA defines investment strategies as "a set of strategies that result from evaluating various levels of funding to achieve State DOT targets for asset condition and system performance effectiveness at a minimum practicable cost while managing risks" [13]. The development of investment strategies for ADOT's bridges and pavements, selected with the goal of closing current and future performance gaps, was influenced by the life cycle planning analysis, risk management analysis, and anticipated available funding presented in previous sections, as well as other factors discussed below.

7.2 Current Performance Gap Assessment

ADOT currently exceeds Federal minimum conditions and meets state performance targets for bridge and pavement performance (Table 41). ADOT has historically met the state targets even when less bridge and pavement funding was available during the Great Recession. The approved WMYA 2040 Long-Range Transportation Plan recommended an increase to the long-term funding for bridges and pavements by about 30%. Based on the life cycle analysis for this TAMP, this increased funding is expected to enable ADOT to continue to meet these performance targets and maintain a state of good repair. Thus, ADOT does not anticipated any performance gaps for the TAMP planning horizon.

Table 41 — Performance Gap Analysis Using Federal Measures & ADOT Targets

Performance Target	2-Year Target	4-Year Target	2018 Performance
Percent of NHS bridges classified as in good condition	52%	52%	57%
Percent of NHS bridges classified as in poor condition	4%	4%	1%
Percent of Interstate pavements in good condition	-	48%	53%
Percent of Interstate pavements in poor condition	-	2%	1%
Percent of non-Interstate NHS pavements in good condition	31%	31%	35%
Percent of non-Interstate NHS pavements in poor condition	6%	6%	4%

7.3 Increased Funding for Asset Preservation

As previously mentioned, ADOT is increasing its investment to preserve Arizona's highway assets. WMYA 2040 recommends investing $326 million annually for asset preservation, about 30% more than current program funding. This type of long-term commitment would make funds available for the preservation treatments described above while continuing to devote adequate funds to restoration of aging assets that have already undergone significant deterioration. Areas of the network that have traditionally received less funding, such as non-Interstate NHS pavements, would receive more investment. This investment combined with the previously mentioned increases to maintenance budget funding for preventative maintenance are expected to be gradually phased in, eventually reversing declining conditions to maintain Arizona's highway system in a state of good repair for the foreseeable future.

7.4 Other Factors Influencing Projected Performance Gaps

7.4.1 Projected Traffic Growth in 2018

Arizona has experienced strong population growth for the past several decades. From 1970 to 2010, the state grew from a population of 1.77 million to 6.39 million. The rate of growth slowed during the Great Recession, but population is still expected to grow another 81% to 11.56 million by 2050 [2].

This growth will lead to increased highway travel. Table 42 shows the projected increase in daily vehicle miles traveled for the SHS (including the State-owned NHS) and locally owned NHS routes between 2016 and 2035.

Table 42 — 2016 and Projected 2035 Daily Vehicle Miles Traveled

Network	2016 Vehicle Miles Traveled	2035 Vehicle Miles Traveled	Percent Increase
SHS Pavement	84,239,889	120,547,062	43.1%
SHS Bridge	10,810,354	12,599,256	16.6%

Note: Projections from the Arizona Statewide Travel Demand Model 2016.

Rising population and the corresponding rise in travel is outpacing the growth of the highway network, resulting in an increased traffic burden on existing roadways. Growing trade with Mexico and freight traffic from Los Angeles ports is contributing to higher truck volumes on key commerce corridors throughout the state. Increased highway utilization, particularly by commercial trucks, accelerates the deterioration of pavements and bridge decks requiring more frequent maintenance, preservation, rehabilitation and reconstruction. Although traffic growth will be gradual, keeping up with impacts will require a substantial investment in infrastructure preservation; it also will make improvements to network-wide asset conditions more challenging.

7.4.2 Infrastructure Age

Over the 10-year horizon of this plan, the advancing age of state highway assets will be one of the primary challenges facing ADOT. Approximately 54% of the bridges on the SHS and the local NHS are more than 50 years old; by the end of the TAMP planning horizon, more than 60% of bridges will exceed this age (Figure 29). Until 2007, ADOT designed bridges to have a 50-year lifespan; however, these bridges may last significantly longer with the proper care. After 2007, new bridges were designed with a service life of 75 years.

Approximately 63% of the pavements on the SHS are more than 50 years old; by the end of the TAMP planning horizon, more than 70% of pavements will exceed this age (Figure 30). Asphalt pavements are designed to last 20 years before an initial rehabilitation is needed. Rehabilitation treatments typically last 10 to 15 years. After two rehabilitation treatments, it is likely to be more cost-effective to reconstruct the pavement making the optimum life cycle of asphalt pavements 40 to 50 years.

Figure 29 — Bridge Age (SHS and local NHS)

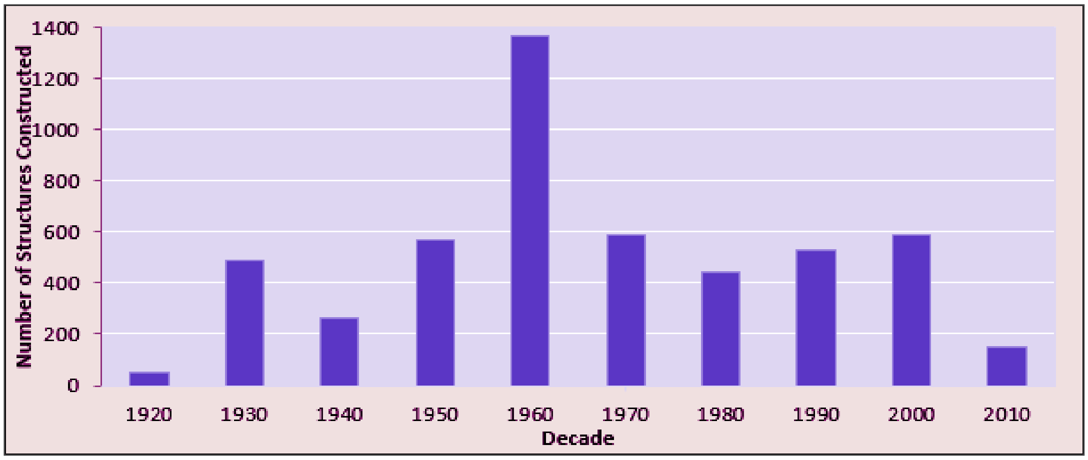
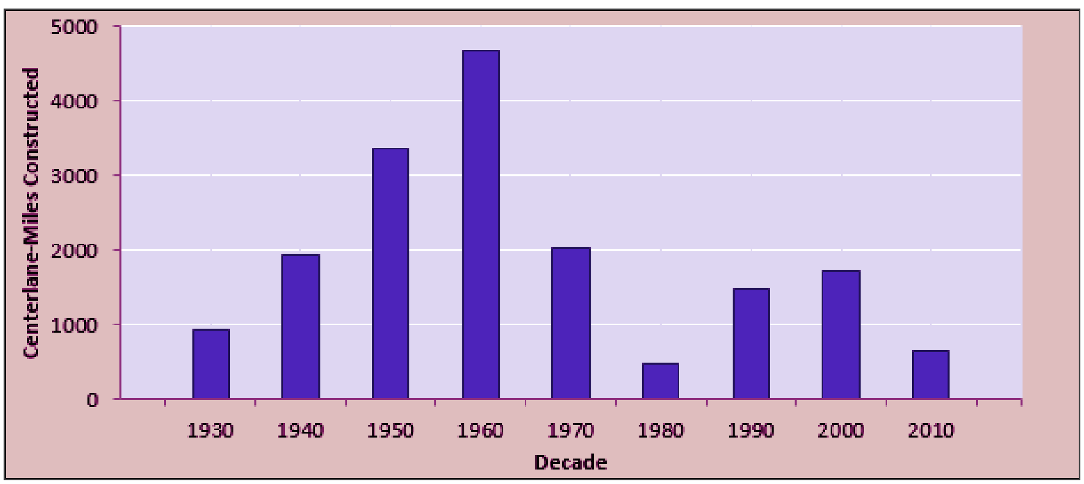


Figure 30 — Pavement Age – State Highway System



Note: Represents initial construction and reconstruction.

7.5 Long-term Outlook

Most of the bridges and pavements on Arizona's highway network were added after the establishment of the interstate freeway system in the mid-1950s. The wear and tear of these assets is showing and increasing the number of fair condition assets in the state.

Assets deteriorate slowly and can accumulate in the fair condition category over a long period. The life cycle analysis that was performed for both bridges and pavements demonstrated that a worst-first strategy, similar to what ADOT has historically used, does little to prevent assets from slipping into the fair condition category and can lead to a situation where costly rehabilitations and replacement outpace the asset management budget. The analysis that includes maintenance and preventative treatments can both slow the rate at which bridge and pavement assets move from good to fair condition while at the same time preventing the fair condition assets from falling into the poor condition category and is more fiscally sustainable over time. For this reason, ADOT is adopting a preservation strategy for the management of bridges and pavements for the TAMP planning horizon.

Additionally, the analysis in WMYA 2040 concluded that more resources would be required to maintain ADOT's bridges and pavements in a state of good repair and recommended that $326 million per year be devoted to these assets. A portion of those funds would be used to increase the amount of bridge and pavement preservation treatments. The State Transportation Board approved WMYA 2040 on February 16, 2018. Although it will take about eight years to phase the full $326 million into the STIP, the long-term increase in preservation spending is expected to slow the decline in bridge and pavement condition over the next decade and support progress toward achieving the ADOT's SOGR. These preservation treatments are described in the next section.

7.6 Life Cycle Analysis

ADOT will gradually increase the use of low cost preservation treatments to extend asset lifespans and reduce the need for costly rehabilitations. These treatments are applied when bridges and pavements are still in good to fair condition to prevent deterioration, maintain the assets in a state of good repair and support the achievement of long-term targets for asset condition.

7.6.1 Bridge

ADOT developed a Bridge Preservation Program (**Appendix A**) that includes cyclical and condition-based preventative maintenance activities to be applied to bridges.

CYCLICAL

- Deck washing (1-2 years)
- Deck sweeping (yearly)
- Cleaning abutment caps and seats, pier caps and seats, and drains (1-2 years)
- Cleaning steel girders and truss bridges (5 years)
- Lubricating bearings and pins (2-5 years)
- Beam end painting/coating (10-15 years)
- Installation of thin bonded polymer overlays such as epoxy or polyester concrete (10-15 years)
- Sealing concrete decks with Methacrylate or other approved sealers (3-5 years)
- Sealing abutment caps and seats, pier caps and seats, pier columns/walls and barriers (3-5 years)

CONDITION-BASED

- Sealing or replacing leaking deck joints
- Eliminating deck joints
- Paint/coating steel bridges
- Installation of scour countermeasures

- Removing channel debris
- Cleaning brush from underneath and around bridges
- Deck patching and repair
- Upgrade to deck drains that meet U.S. Environmental Protection Agency standards
- Repairing slope paving

7.6.2 Pavement

As mentioned in the Risk Management Analysis section, ADOT is requesting to more than double the size of the surface treatment program budget to enable a larger percentage of the pavements to receive surface treatments, including:

- Fog coat
- Pre-coated chip seal with terminal blend polymerized asphalt rubber (TR+)
- Crumb rubber asphalt chip seal
- Micro surfacing and slurry seal
- Crack fill, crack seal, wide crack mastic and concrete joint sealing
- Spot repairs and patching
- 1-inch thin bonded overlay
- 2.5-inch Asphaltic Concrete mill and replace surface spot repair
- Asphalt rubber-asphaltic concrete friction course (AR-ACFC or ACFC)

ADOT is currently undertaking a pavement life extension test project in support of a *FHWA Every Day Counts 4* initiative to test micro surface cape seal and slurry surface cape seal. The project is being performed on State Route 260 in Heber at an elevation of 6,600 feet. Two treatment options are being tested:

TREATMENT #1 – HEAVY DUTY CAPE SEAL

- 0.5-inch mill (clean surface)
- Crack fill – asphalt rubber and mastic (1.5-inch and larger)
- Type 3 micro surface on a TR+ chip seal

TREATMENT #2 – MEDIUM DUTY CAPE SEAL

- 0.5-inch mill (clean surface)
- Crack fill – asphalt rubber and mastic (1.5-inch and larger)
- Type 3 slurry seal on a TR+ chip seal

If successful, these long-lasting cape seal treatments will be included in the surface treatment program.

The development of bridge and pavement preventative maintenance programs is a work in progress and will require a long-term commitment to be successful.

7.7 Investment Strategies Methodology

Preserving the performance and condition of the state's transportation system requires a long-term financial plan that supports the implementation of the life-cycle strategies documented earlier in this TAMP. Based on the expected funding available for managing pavements and bridges over the next 10 years, ADOT analyzed different combinations of investments in maintenance, preservation, rehabilitation, and reconstruction to determine their impact on future conditions. The selected strategies build on the results of the LCP described in Section 4 and consider the risks documented in Section 5 and the financial plan in Section 6. In addition, the recommended strategies aim to ensure that no performance gaps occur over the TAMP period, but instead, achieve a state of good repair for both bridge and pavement assets. The resulting investment strategies reflect an increased investment in preservation activities and a shift away from the worst-first approach used in the past. This increased use of low-cost treatments slows the rate of asset deterioration, extends the useful life of an asset and defers the need for more costly rehabilitation treatments. These treatments are applied to pavement and bridges while they are still in Good or Fair condition to keep these assets in a state of good repair.

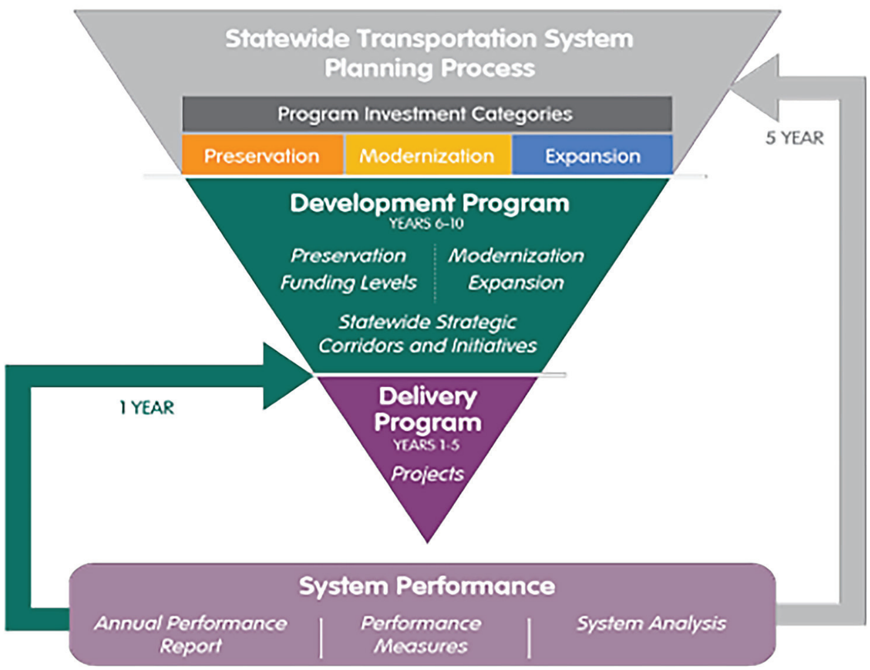
The process that was followed to identify a recommended investment strategy is described below.

- **Develop investment strategies**. The TAMP technical team provided several long-term, fiscally-constrained funding scenarios to the asset managers so that different treatment strategies could be considered. The strategies analyzed by the asset managers considered different combinations of maintenance, preservation, rehabilitation, and reconstruction to achieve and sustain a state of good repair over asset life cycles, while achieving performance targets, supporting national goals, and managing risks. The strategies were evaluated based on their ability to achieve a state of good repair, the degree to which the desired LCP strategies are followed, the ability to implement the levels of investment over 10 years, and their impact on agency risks.
- **Attempt to close funding gaps**. One of the primary considerations in evaluating the investment strategies was whether a performance gap existed between desired and projected conditions. Where funding gaps did exist, ADOT considered various methods of closing the funding gaps, including shifting resources, lowering performance targets, changing LCP strategies, or increasing risk tolerance. Impacts to other performance areas were also considered in selecting the best overall investment strategies for the transportation system overall. In the end, ADOT was able to develop a recommended investment strategy that did not result in a funding gap for pavements or bridges.
- **Determine the recommended investment strategy.** The technical team worked with agency management to determine the recommended investment strategies and funding levels for pavements and bridges over the next 10 years. The results from different investment scenarios were presented to the team during an Investment Workshop conducted in April 2019. Based on the results, several additional scenarios were evaluated, and management selected the strategies that are presented in this TAMP.
- **Incorporate recommended investment strategies into the planning and programming process**. The recommended investment strategies fit into a larger context of transportation performance management and performance-based planning and programming. Safety, mobility, and commerce also are important transportation needs that are considered during the long-range transportation planning process. Since transportation needs outpace available funding, ADOT must make difficult choices about where to best spend limited resources. To ensure the best choices, ADOT started using a data-driven, performance-based approach to planning, programming, and financial decision making that connects the goals of the state's performance-based Long-Range Transportation Plan to the ADOT Five-Year Construction Program and the Statewide Transportation Improvement Program

(STIP), known as P2P Link. To incorporate longer-term planning into the process, ADOT added a development program representing an additional five years (years 6 through 10) of tentative programming that feeds the five-year transportation facilities construction program.

Planning documents like the TAMP, Freight Plan, and other major corridor studies inform the development of high-level recommended investment choices in the Long-Range Transportation Plan and support the achievement of performance targets by providing category-specific investment strategies that can be used to develop a package of projects for the 10-year Development Program and the STIP, as shown in Figure 31. For bridges and pavements, the recommended investment strategies in this TAMP will serve as the primary basis for selecting and prioritizing projects throughout this process.

Figure 31 — Linking Planning to Programming



SOURCE: PARSONS BRINCKERHOFF 2014

7.8 Risk Management & Initial Construction

The following investment strategies were adopted by ADOT to address risks associated with bridges and pavements:

- Scour counter measures subprogram. $2–3 million annually has been allocated to implement scour counter measures on scour critical bridges. This subprogram is expected to continue into the future.
- Culvert repair subprogram. In FY 2018, $4.3 million was allocated to repair culverts that exhibit significant blockage and rusting.
- Capital improvement and management of pump stations. ADOT is developing tools for the improvement and management of Phoenix area pump stations, which would help prevent flood damage on the state's largest urban freeway network.

- Installation of weigh-in-motion stations. In calendar year 2017, approximately $1.3 million was invested for the construction of WIM stations to detect unpermitted overweigh trucks which can damage both bridges and pavements.
- Increased funding for pavement surface treatments. For FY 2020, the pavement surface treatment budget was increased from $40.6 million to $52.1 million to increase the amount of preventative surfaces treatments that can be applied to Arizona highways.

Some of these funds (e.g., scour countermeasures fund) are ongoing and will continue until the risks are mitigated. Risks that have a lower likelihood, such as rock fall remediation, are addressed using contingency funds or the redistribution of program funds.

In addition to the amount planned to be invested in preserving the system described in the following sections, additional funds are anticipated for new construction (Table 43). New construction projects are typically programmed to address safety and mobility issues that are designed to improve the overall performance of the network on a system wide basis and add new capacity due to population growth. For planning purposes, it is assumed that 100% of the new construction will take place on the NHS.

Table 43 — Planned investments in bridge and pavement new construction over the 10-year period from FY19-FY28 (in Millions).

Fiscal Year	Amount	FY	Amount
2019	619	**2024**	99
2020	778	**2025**	0
2021	809	**2026**	0
2022	514	**2027**	0
2023	191	**2028**	0

7.9 Bridge Investment Strategies

In its investigation of investment alternatives for the Arizona bridge inventory, ADOT considered the following two alternatives scenarios over a ten-year period, generating outputs using AASHTOWare Bridge Management (BrM):

- A "worst-first" strategy, where only the bridges in worst condition receive any treatment
- A preservation strategy which strategically balances funding allocation between maintenance, preservation, rehabilitation and reconstruction

For each scenario considered, funding was allocated to determine whether the desired bridge state of good repair could be achieved. As a reminder, the desired state of good repair for bridges was defined in terms of a targeted percent of the network deck area in Good condition and a maximum amount of the network deck area in Poor condition (Section 3.4.2). The portion of the network not represented by Good or Poor definitions is in Fair condition.

7.9.1 Recommended Bridge Investment Strategy

The evaluation of the various investment strategies led ADOT to select a planned program of investment that reflects a balanced investment in preservation work types over a worst-first approach.

7.9.1.1 Funding and Treatment Distributions

Scenarios for bridge preservation were developed separately for the SHS and for the NHS. The SHS scenarios include all state-owned bridges, on or off the NHS, thus reflecting all ADOT resources available for investment in existing bridges. The NHS scenarios include an allowance for local investment in the small fraction (6.4% by deck area) of NHS bridges that are locally-owned. Table 44 shows the annual funding levels that were projected. Note that the funding shown here is an annual average that incorporates the expected gradual increase in preservation investments referenced in Section 7.3.

Table 44 — Bridge investment scenarios – assumed funding levels ($ millions)

Fiscal Year	SHS	NHS
2019	$ 82	$ 59
2020	$ 82	$ 59
2021	$ 82	$ 59
2022	$ 82	$ 59
2023	$ 82	$ 59
2024	$ 82	$ 59
2025	$ 82	$ 59
2026	$ 82	$ 59
2027	$ 82	$ 59
2028	$ 82	$ 59

The best scenario at most likely funding levels features the breakdown of work categories shown in Table 45. This breakdown would likely be the same for any realistic funding level on or off the NHS. BrM is not yet able to optimize the allocation of funding among treatment types, so this assumed breakdown was applied as a constraint, reflecting an ADOT concept of a robust preservation program implemented immediately.

Table 45 — Bridge funding allocation by work types at predicted funding level

		ANNUAL DOLLARS ($MILLIONS)	
Work Type	**Percent of Dollars**	**SHS**	**NHS**
Maintenance	5%	$4.1	$2.9
Preservation	20%	$16.4	$11.8
Rehabilitation	40%	$32.8	$23.6
Reconstruction	35%	$28.7	$20.7
Total	**100%**	**$82.0**	**$59.0**

7.9.1.2 Predicted Conditions

The preservation scenario met ADOT SOGR targets. Table 46 summarizes the scenario output.

Table 46 — Projected conditions over the 10-year period

	% GOOD BRIDGE SQ FT.		% POOR BRIDGE SQ FT.	
	Target Good %	Projected % Good (Year 10)	Target % Poor	Projected % Poor (Year 10)
NHS	22.0%	22.8%	4.0%	0.9%
SHS	22.0%	22.9%	4.0%	1.1%

The scenario shows a decline from the current 56% Good, over the next ten years. This is driven mainly by the aging of many of Arizona's largest bridges. Thus far, the BrM analysis is inconclusive as to whether the decline will increase long-term costs, but the experiences of other agencies indicate that this is likely. This makes it a priority to carry out the life cycle planning work plan discussed in Section 4 to improve ADOT's capability to forecast future conditions and costs, so a more definitive plan can be developed.

7.9.1.3 Planned 10-Year Bridge Investment

Using the annual funding level and planned breakdown of expenditures, Table 47 shows the projected investment separately for the NHS and the SHS.

Table 47 — Planned annual investment over the 10-year period from FY19-FY28 (in Millions)

($ Millions)	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
NATIONAL HIGHWAY SYSTEM (INCLUDING STATE AND LOCAL NHS)											
Maintenance	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	**29.0**
Preservation	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	**118.0**
Rehabilitation	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6	**236.0**
Reconstruction	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	**207.0**
Total NHS	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**59.0**	**590.0**
STATE HIGHWAY SYSTEM (INCLUDING NHS AND NON-NHS)											
Maintenance	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	**41.0**
Preservation	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	**164.0**
Rehabilitation	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	32.8	**328.0**
Replacement	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	**287.0**
Total SHS	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**82.0**	**820.0**

7.9.2 Bridge Performance Gap Analysis

A comparison of the 10-year targeted bridge conditions and the conditions projected to be achieved by implementing the most likely bridge funding investment strategy was presented earlier as Table 46. As shown, ADOT is expected to achieve its desired state of good repair over the 10-year analysis period so there is no gap expected in bridge conditions.

7.10 Pavement Investment Strategies

As discussed in the LCP section, ADOT is making a commitment to increase the level of investment in maintenance and preservation activities to defer the need for costly rehabilitation treatments and reduce the life cycle cost of managing the pavement network. ADOT initially envisioned that the pavement investment strategies would be evaluated using the new pavement management software, but the implementation was not completed in time to make that practical. Instead, the Excel-based tool that is described in the Section 4 was used to analyze the various pavement strategies over a 10-year period. Several different financial scenarios were considered during the Investment Workshop, including those listed below:

- A preservation strategy with initial expected levels of funding ($2.304 Billion over 10 years for the state-maintained system and $380 Million for the locally maintained NHS).
- A preservation strategy with increased funding in years 6 to 10 ($2.411 Billion over 10 years for the state-maintained system and $380 Million for the locally maintained NHS).
- The funding level needed to meet the desired state of good repair.
- The funding level needed if up to 5% Poor was allowed on the Interstates and up to 10% Poor was allowed on the rest of the system.

The last two scenarios were analyzed to enable ADOT to estimate its financial gap over the next 10 years. The risks associated with increasing the percent of the network in Poor condition, as represented by the last of the four scenarios listed above, were considered too high to be acceptable because it represented a dramatic shift from current conditions and would hinder ADOT's ability to meet its overall system performance objectives. For these reasons, that scenario was eliminated from further consideration.

Following the Investment Workshop, an additional financial scenario was analyzed, reflecting the additional $10.5 M annually to be used primarily for pavement maintenance and preventive maintenance activities ($2.409 Billion over 10 years for the state-maintained system and $380 Million for the locally maintained NHS).

For each scenario considered, funding was allocated to each pavement class to determine whether the desired pavement state of good repair could be achieved. As a reminder, the desired state of good repair for pavements was defined in terms of a targeted percent of the network in Good condition and a maximum amount of the network in Poor condition (Table 11). The portion of the network not represented by Good or Poor definitions is in Fair condition.

The funding allocated to pavement condition categories represented different categories of repair, as described below.

- **Good condition:** Pavements in Good condition are not considered for repair immediately after construction or major rehabilitation treatments have been applied but are candidates for maintenance several years later to fill cracks and rejuvenate the asphalt surface.
- **Fair condition:** Pavements in Fair condition are eligible for preservation treatments such as chip seals and microsurfacing to slow the rate of deterioration and address surface characteristics.
- **Poor condition:** Pavements in Poor condition may initially be candidates for rehabilitation, which typically includes milling off the exiting surface and replacing it with 4.5 to 5 inches of asphalt to eliminate the deterioration that exists. Over time, pavements in Poor condition become candidates for reconstruction when both the surface and underlying layers need to be replaced.

Based on ADOT's commitment to increasing the amount of investment in preservation treatments, varying levels of investment in each of the treatment categories were considered to maximize the predicted conditions at the end of the 10-year period.

7.10.1 Recommended Pavement Investment Strategy

The evaluation of the various investment strategies led ADOT to select a planned program of investment that reflects an increased investment in preservation immediately that continues over the duration of the 10-year period. The strategy also reflects a continued investment in rehabilitation activities to address the deterioration expected on portions of the system, but minimal reliance on reconstruction.

In addition, the strategy assumes a level of investment by the local agencies managing a portion of the NHS. For that portion of the system, ADOT assumed that some preservation work would be done, but recognized that most of the locally managed NHS would receive rehabilitation or reconstruction in conjunction with regional plans to update or expand existing facilities. ADOT will work with the MPOs to ensure the most optimal use of available funds for this portion of the network.

7.10.1.1 Funding and Treatment Distributions

The pavement investment strategy used a total 10-year budget of $2.409 billion (state) and $0.38 billion (local) distributed as shown in Table 48. Note that the funding shown here incorporates the expected gradual increase in preservation investments referenced in Section 7.3.

Table 48 — Assumed funding over 10 years

Fiscal Year	Assumed State Pavement Budget (in Millions)	Assumed Local Pavement Budget (NHS Only) (in Millions)
2019	$247.5	$38
2020	$216.5	$38
2021	$152.5	$38
2022	$179.5	$38
2023	$217.5	$38
2024	$205.5	$38
2025	$277.5	$38
2026	$297.5	$38
2027	$297.5	$38
2028	$317.5	$38
Total	**$2,409**	**$380**

The available funding each year was divided by asset class, as noted in Table 49. The funding for the locally maintained NHS was allocated entirely to that portion of the NHS. For planning purposes, no state funding was assumed to be allocated to the locally maintained NHS pavements.

Table 49 — Allocation of projected state funding over 10 years.

Pavement Category	Pavement Class	Percent of State Funding Allocated Over 10 Years	Total Amount Allocated Over 10 Years (In Millions)	Total Amount Allocated Over 10 Years for NHS and Non-NHS (in Millions)
NHS	Interstates	32%	$770.88	$1,638
	State-Maintained NHS	36%	$867.24	
	Locally-Maintained NHS	0%	$0	
Non-NHS	High Volume	7%	$168.63	$771
	Low Volume	25%	$602.25	
	Totals	**100%**	**$2,409**	**$2,409**

The spreadsheet tool was used to allocate funding into each of four treatment categories, including maintenance, preservation, rehabilitation (including both major and minor rehabilitation), and reconstruction. The recommended strategy used the allocation of funding shown in Table 50 over the 10-year analysis period. The distribution of funds reflects a significant increase in the amount of pavement preservation being applied in each of the next 10 years. It also reflects limited to no spending for reconstruction activities since most of the pavement network will be managed in a way to keep it in Good or Fair condition. The exception to this is the low-volume non-NHS pavements, which are expected to deteriorate significantly over the analysis period. Even though conditions on this portion of the network are expected to deteriorate, reconstruction has not been used historically on this portion of the network, which is consistent with the funding distribution presented in Table 49.

Table 50 — Funding distribution by treatment type.

		Percent of Funds Allocated To:				
Pavement Category	**Pavement Class**	**Maintenance**	**Preservation**	**Rehabilitation**	**Reconstruction**	**Totals**
NHS	Interstates	8%	32%	56%	4%	100%
	State-Maintained NHS	8%	36%	55%	1%	100%
	Locally Maintained NHS	5%	15%	55%	25%	100%
Non-NHS	High Volume	6%	42%	51%	1%	100%
	Low Volume	15%	52%	33%	0%	100%

7.10.1.2 Predicted Conditions

The implementation of the recommended 10-year investment strategy is expected to result in the conditions reflected in Table 51. As shown in the table, the investment strategy achieves the percent Good targets for each pavement class and does not exceed the percent Poor targets for all systems. At no time over the 10-year period is the Interstate pavement network expected to exceed the Federal minimum condition target of 5% Poor.

Table 51 — Projected conditions over the 10-year period.

		% Good PAVEMENT Miles		% Poor PAVEMENT Miles	
	Class Category	**Target % Good**	**Projected % Good (Year 10)**	**Target % Poor**	**Projected % Poor (Year 10)**
NHS	Interstate	58%	58%	1%	<1%
	State-Maintained NHS	40%	41%	3%	3%
	Locally-Maintained NHS	5%	34%	8%	7%
Non - NHS	High-Volume	35%	37%	4%	4%
	Low-Volume	30%	30%	36%	36%
MINIMUM Check: % Interstates in POOR condition:				**<1%**	**Target: <= 5%**

7.10.1.3 Planned 10-Year Pavement Investment

On an annual basis, the recommended pavement strategy reflects the distribution of investment in maintenance, preservation, rehabilitation, and reconstruction for the state-maintained system shown in Table 52. In addition to the amount shown for the NHS, local agencies are projected to invest $38 Million annually on the locally managed NHS in the following categories:

- Annual expenditures for maintenance on the locally managed NHS: $1.9 Million
- Annual expenditures for preservation treatments on the locally managed NHS: $5.7 Million
- Annual expenditures for rehabilitation on the locally managed NHS: $20.9 Million
- Annual expenditures for reconstruction on the locally managed NHS: $9.5 Million

Table 52 — Planned annual investment by ADOT over the 10-year period from FY19-FY28 (in Millions).

		FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	Totals
NHS *(excludes locally managed NHS)*	Maintenance	$13.48	$11.78	$8.30	$9.76	$11.83	$11.18	$15.10	$16.18	$16.18	$17.27	$131.07
	Preservation	$57.49	$50.23	$35.38	$41.64	$50.46	$47.68	$64.38	$69.02	$69.02	$73.66	$558.96
	Rehabilitation	$93.47	$81.66	$57.52	$67.71	$82.04	$77.51	$104.67	$112.22	$112.22	$119.76	$908.79
	Reconstruction	$4.06	$3.55	$2.50	$2.94	$3.57	$3.37	$4.55	$4.88	$4.88	$5.21	$39.51
Total NHS		**$168.50**	**$147.22**	**$103.70**	**$122.06**	**$147.90**	**$139.74**	**$188.70**	**$202.30**	**$202.30**	**$215.90**	**$1,638.32**
Non-NHS	Maintenance	$10.33	$9.03	$6.36	$7.49	$9.07	$8.57	$11.57	$12.41	$12.41	$13.24	$100.47
	Preservation	$39.50	$34.51	$24.31	$28.61	$34.67	$32.76	$44.23	$47.42	$47.42	$50.61	$384.04
	Rehabilitation	$29.29	$25.59	$18.03	$21.22	$25.71	$24.29	$32.80	$35.16	$35.16	$37.53	$284.78
	Reconstruction	$0.17	$0.15	$0.11	$0.13	$0.15	$0.14	$0.19	$0.21	$0.21	$0.22	$1.69
Total Non-NHS		**$79.30**	**$69.28**	**$48.80**	**$57.44**	**$69.60**	**$65.76**	**$88.80**	**$95.20**	**$95.20**	**$101.60**	**$770.98**
Total 10-Year State Spending		**$247.80**	**$216.50**	**$152.50**	**$179.50**	**$217.50**	**$205.50**	**$277.50**	**$297.50**	**$297.50**	**$317.50**	**$2,409.00**

7.10.2 Pavement Performance Gap Analysis

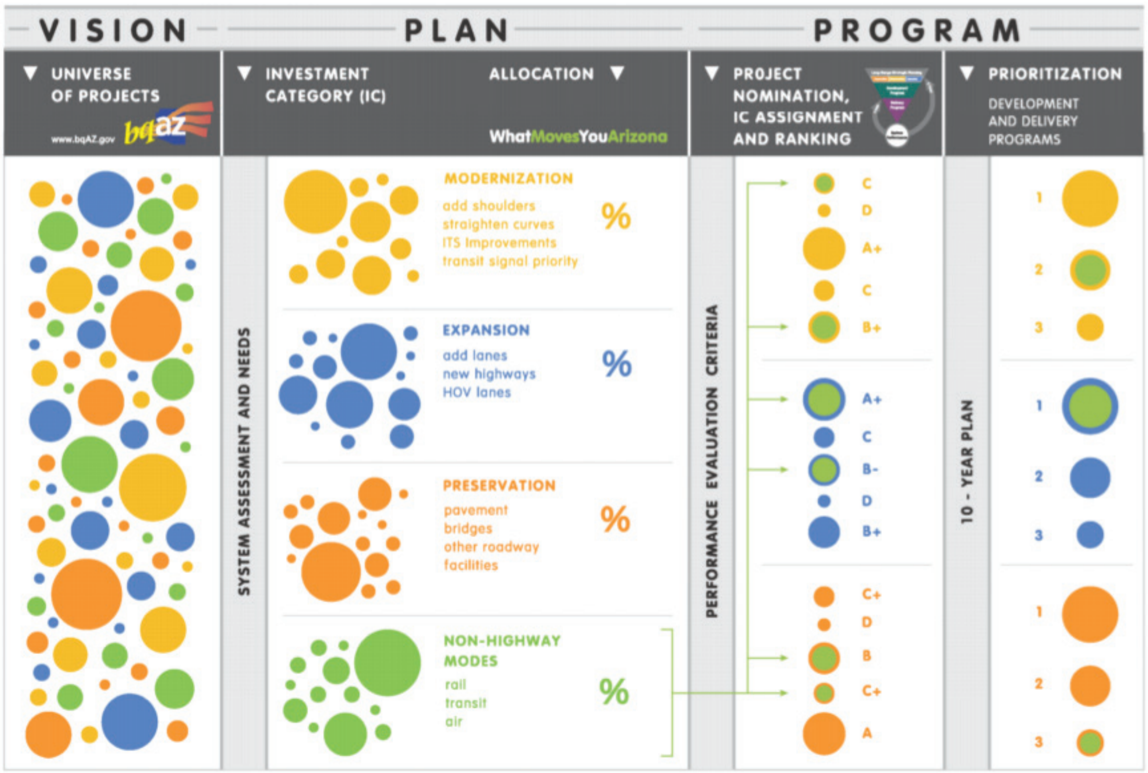
A comparison of the 10-year targeted pavement conditions and the conditions projected to be achieved by implementing the recommended pavement investment strategy was presented earlier as Table 50. As shown, ADOT is expected to achieve its desired state of good repair over the 10-year analysis period so there is no gap expected in pavement conditions.

7.11 Consideration of System Performance

When considering the selection of pavement and bridge improvement projects, ADOT uses an objective, data-driven approach to consider the needs within each performance area to maintain the overall performance of the transportation system. In addition to attention to pavement condition needs, this involves consideration of safety, mobility, freight, economic vitality, and environmental sustainability objectives through ADOT's Planning to Programming (P2P) process. This performance-based process connects ADOT's Vision and Long-Range Transportation Plan (WMYA 2040) to the Five-Year Construction Program in a transparent, defensible, logical, and reproducible way. The P2P process was initially developed in 2014 to help align ADOT's efforts under the MAP-21 legislation. Since then, ADOT has refined its P2P process to better align expenditures with strategic objectives and to provide for the most cost-effective use of Arizona's transportation dollars.

Under P2P, projects are selected for funding based on their contribution to the improvement of system performance when compared to other projects. Once projects are programmed, the performance of the system is assessed based on the contribution of the programmed projects on the system. The implementation of P2P has enabled ADOT to develop a more comprehensive set of procedures for targeting and measuring performance and a more strategic allocation of resources based on priorities reflective of each project's contribution to system performance. These changes are helping to ensure that ADOT is using transportation funds effectively by better aligning project scope and priority with system performance priorities, representing a range of competing objectives, as shown in Figure 32. This TAMP serves as the foundation for evaluating asset preservation needs for pavements and bridges on a statewide basis as part of this process.

Figure 32 — ADOT's P2P approach to system wide investments.



Moving forward, ADOT will continue to monitor impacts caused by the implementation of the P2P process to support the state's economic vitality and to provide a safe and efficient transportation system.

Section 8
Continuous Improvement

Generally, the TAM process is a continuous one with course-corrections expected along the way, as an agency matures in its asset management practice. This document should be viewed as a living document, to be updated as ADOT continues to improve asset management and preservation activities, towards a state of good repair. Per Federal regulations, this TAMP is required to be updated every four years with revised processes submitted for recertification. In addition, FHWA will be conducting an annual consistency determination, to ensure that the plan is implemented. Between iterations of TAMP versions and the annual consistency determination, there will be opportunities to improve ADOT's TAM practice and compliance with Federal regulations.

Based on the current state of TAM at ADOT and the gaps identified in TAM practice during the development of this document, the following opportunities for improvement have been identified for consideration:

- Complete implementation of dTIMS pavement management system and conduct life cycle planning to generate more detailed projections;
- Implement the work plan identified in **Section 4.3** for AASHTOWare Bridge Management System (BrM 6.0) process enhancements and in **Section 4.4** for dTIMS pavement management system enhancements.
- Update the TAMP to reflect any changes to investment strategies and/or performance targets using the updated management systems
- Develop guidance to ensure that pavement and bridge preservation treatments are used effectively, as outlined in the TAMP

ADOT will continue to work to improve management of bridge and pavement assets on both the NHS and the SHS with the overall goal of achieving a sustained state of good repair.

Section 9
References

1. Arizona Management System (AMS). 2018. AMS in Focus Newsletter Vol.2, Issue 1; Governor's Transformation Office. https://ams.az.gov/sites/default/files/180117%20AMS%20In %20Focus-V2-1.pdf. January 17, 2018.

2. Arizona Long Range Plan Working Paper WMYA 2040, Arizona Department of Administration projections. 2016.

3. Arizona Department of Transportation (ADOT). 2011. What Moves you Arizona; Long-Range Transportation Plan 2010 – 2035.

4. FHWA, Risk-Based Transportation Asset Management: Managing Risks to Networks, Corridors, and Critical Structures 2012.

5. Federal Highway Administration (FHWA). 2012. Risk-Based Transportation Asset Management: Evaluating Threats, Capitalizing on Opportunities – Overview of Risk Management 2012.

6. Arizona Department of Transportation (ADOT). 2013. Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona. March 2013.

7. Arizona Department of Transportation (ADOT). 2015. Extreme Weather Vulnerability Assessment. January 2015.

8. HDR. 2016. ADOT Phoenix District Pump Station Evaluation.

9. Arizona Department of Transportation (ADOT). 2006. ADOT Research Center Study: Estimating the Cost of Overweight Vehicle Travel on Arizona Highways; Report 528; Straus-Semmens. January 2006

10. National Cooperative Highway Research Program. 2004. Report 523, "Optimal Timing of Pavement Preventative Maintenance Treatment Applications."

11. Federal Highway Administration (FHWA). 2017a. Developing TAMP Financial Plans, November 2017.

12. Arizona Highway User Revenue Fund Forecasting Process & Results. 2017. FY 2018-2027, FMS September 2017.

13. Federal Highway Administration (FHWA). 2017b. Using a Life Cycle Planning Process to Support Asset Management-Interim Document. June 2017.

14. Parsons Brinckerhoff. 2014. P2P Link Methodologies and Implementation Plan, June 2014.

Section 10
Glossary of terms

Asset — A physical component or resource related to the transportation infrastructure.

Asset Class — A grouping of the same type of asset, such as bridges.

Asset Management — A strategic and systematic process of operating, maintaining and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost. (23 United States Code 101(a)(2))

Asset Sub-class — A subset of an asset class, such as steel bridges.

Bridge component — A major functional unit of a bridge (e.g., deck, superstructure, substructure).

Bridge element — A sub-component of a bridge (e.g., expansion joint, girder).

Deterioration model — A mathematical model that predicts the future condition of an asset, if only minimal or routine maintenance is performed.

Expansion — Increasing transportation system traffic volume capacity by expanding a roadway or constructing a new transportation facility.

Long Range Transportation Plan — Federal regulations (23 United States Code 135) require states to develop a long-range statewide transportation plan that provides for the development and implementation of the intermodal transportation system. The plan must cover a minimum of 20 years and be developed in consultation with local governments and other parties within the state. ADOT's plan covers 25 years and is updated every five years.

Maintenance — Routine activities that maintain the functional condition of existing roadways.

Modernization — Improvements to address functional, safety and geometric deficiencies.

Performance (transportation asset) — The condition of an asset, specifically how well and safely it fulfills its intended function and lifespan.

Performance Gap — The difference between an asset's current condition and the desired condition.

Preservation (Work Type) — A program of preventative maintenance that extends asset service life and maintains the functional condition of existing roadways. Repairs and minor rehabilitation that don't restore or enhance the structural capacity of an asset also are included in the category. The terms preventative maintenance or preservation treatments may be used convey this meaning in the TAMP.

Preservation (Planning) — For planning purposes, ADOT uses this term to describe all the activities and work types needed to maintain transportation infrastructure meeting the functional requirements of the as built highway system. Often this usage will be in conjunction with the terms modernization and expansion.

Preventative maintenance — Periodic maintenance that is applied when an asset is in good condition to prevent deterioration and extend asset life.

Rehabilitation — Treatments that restore or strengthen an asset's structural capacity to extend service life and/or increase load carrying capability.

Reconstruction or replacement — Replacement of an entire asset to restore or update functionality and/or increase traffic volume capacity.

State Transportation Implementation Plan (STIP) —Federal regulations (23 United States Code 135) require that states develop a STIP containing a fiscally-constrained listing of projects covering a minimum of four years and developed in consultation with local governments and other parties in the state. ADOT's STIP covers five years and is updated annually.

Work Type — Refers to initial construction, maintenance, preservation, rehabilitation and reconstruction (23 CFR 515.5).

Section 11
Acknowledgements

The Initial TAMP was prepared by:

Thor Anderson, Asset Manager, ADOT Multimodal Planning Division
206 S. 17th Avenue, Mail Drop 310B, Phoenix, AZ 85007
TAnderson@azdot.gov

Special thanks go to the following people who contributed information and assistance for the development of the TAMP and/or participated in the Risk Workshop:

ADOT

David Eberhart, P.E.
David Benton, P.E.
Pe-Shen Yang, Ph.D., P.E.
Henry Sung, P.E
Clifton Guest, P.E.
Yongqi Li, Ph.D., P.E.
Mafiz Mian, P.E.
Kevin Robertson, P.E.
Gregory Byres, P.E.
Clem Ligocki
Scott Weinland, P.E.
Charla Glendening, AICP
Bret Anderson
Lynn Sugiyama
Ryan Blum
Shaun Perfect
Patrick Whiteford, GISP
Keith Killough, AICP
Baloka Belezamo, P.E.
Lisa Danka
Patrick Stone
Maria Leon
Melissa Manfrida
Keith Fallstrom
Karuna Ramisetty, CPA
James Meyer, GISP
Cyndi Striegler
Christopher Freitag, CPA
Christ Dimitroplos, P.E.
Brent Conner, P.E.
J.J. Liu, P.E.
Bernadette E. Phelan, Ph.D.
Steve Kalina
Paul Simpson
Steve Olmsted
Ted Howard
Tracy Clark
James Windsor, P.E.
Masudur Rahman, P.E.
Amin Aman, P.E.
Ramon Gama

Consultant Team

Margaret-Avis Akofio-Sowah, Ph.D. (WSP)
Justin Feek (WSP)
Juan Diego Porras-Alvarado, Ph.D. (WSP)
Gareth McKay (WSP)
Katie Zimmerman P.E. (Applied Pavement Technologies)
Paul Thompson
Brad Allen, P.E. (Applied Pavement Technologies)

FHWA

Chad Matty, P.E.

Section 12
Appendix A: Documents referenced

All documents listed below may be found at: www.azdot.gov/tamp

1. What Moves You Arizona 2040, Long-Range Transportation Plan
2. MPO/COG Planning Agreements
3. Bridge Inspection Guidelines
4. ADOT/City of Phoenix Bridge Inspection Intergovernmental Agreement
5. Pavement Data Quality Management Plan
6. Preliminary Study of Climate Adaptation for the Statewide Transportation System
7. Extreme Weather Vulnerability Assessment
8. Asset Management, Extreme Weather, and Proxy Indicators Infrastructure Resilience Report
9. Evaluation of the State Route (SR) 87 Landslide and Related Slope Stability Issues
10. Arizona Long Range Transportation Plan Update. Recommended Investment Choice (RIC) Development. October 2017.
11. Arizona Long Range Transportation Plan Update. Existing Conditions, Deficiencies and Future Needs. February 2017.
12. Arizona Long Range Transportation Plan Update. Revenue Forecast and Gap Analysis. April 2017.
13. Arizona Highway User Revenue Fund Forecasting Process & Results FY 2019-2028
14. Maricopa County Transportation Excise Tax Forecasting Process & Results
15. Bridge Preservation Program