Operationalizing Sustainable Transportation and FHWA's INVEST Operations & Maintenance Implementation – 2nd Annual Arizona Department of Transportation Sustainable Transportation Program Final Report

U.S. Department of Transportation
Federal Highway Administration

ADOT
Infrastructure Delivery and Operations

INVEST
ECONOMIC • SOCIAL • ENVIRONMENTAL

Infrastructure Voluntary Evaluation Sustainability Tool

Operationalizing Sustainable Transportation and FHWA's INVEST Operations & Maintenance Implementation – 2nd Annual Arizona Department of Transportation Sustainable Transportation Program Final Report

Arizona Department of Transportation
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Cambridge Systematics, Inc.

List of Acronyms

ADOT	Arizona Department of Transportation
AID	Accelerated Innovation Deployment
AMP	Automated Motor Vehicle Pool
ASD	Administrative Services Division
AVL	Automatic Vehicle Location
AZ-TAMS	Arizona Transportation Asset Management System
BMP	Best Management Practices
BMS	Bridge Management System
CISP	Comprehensive Internal Sustainability Plan
COG	Council of Government
CSS	Context Sensitive Solutions
DEC	District Environmental Coordinator
DOT	Department of Transportation
EASPD	Excellence in Advancing Sustainable Project Development
ECTS	Environmental Compliance Tracking System
EDC	Every Day Counts
FAST	Fixing America's Surface Transportation Act
FIS	Feature Inventory System
FHWA	Federal Highway Administration
GHG	Greenhouse Gas (Emissions)
GIS	Geographic Information System
GRS-IBS	Geosynthetic Reinforced Soil–Integrated Bridge System
HFST	High Friction Surface Treatments
HPMS	Highway Performance Monitoring System
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
IRI	International Roughness Index
ITD	ADOT Intermodal Transportation Division
ITS	Intelligent Transportation Systems
LCCA	Life Cycle Cost Analysis
LED	Light-Emitting Diode
LNG	Liquefied Natural Gas
LOS	Level of Service
LPA	Local Public Agency
MMS	Maintenance Management System
MPD	ADOT Multimodal Planning Division
MPO	Metropolitan Planning Organization
MQA	Maintenance Quality Assurance
NBI	National Bridge Inventory
NEPA	National Environmental Policy Act
NBIP	Needs-Based Implementation Plan
OFA	Operational Focus Areas
OM	Operations and Maintenance
PD	Project Development
PeCoS	Performance Controlled System (an ADOT maintenance management system)
PIN	Personal Identification Number

Acronyms	**continued**
PMS	Pavement Management System
REC	Renewable Energy Credit
RMP	Road Maintenance Plan
RWIS	Roadway Weather Information System
RWMP	Road Weather Management Program
SEO	State Engineer's Office
SFA	Strategic Focus Areas
SHSP	Strategic Highway Safety Plan
SOP	Standard Operating Procedure(s)
SPR	System Planning for Regions
SPS	System Planning for States
SR	State Route
STIC	State Transportation Innovation Council
STIP	State Transportation Improvement Program
STWG	Sustainable Transportation Working Group
TAMP	Transportation Asset Management Plan
TCB	Temporary Concrete Barriers
TCMP	Traffic Control Maintenance Plan
TSMO	Transportation System Management and Operations
TRB	Transportation Research Board
WZTC	Work Zone Traffic Control

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Sustainable Transportation

Planning, Developing and Maintaining for the Public Good

The Arizona Department of Transportation (ADOT) recognizes the critical need to plan and prioritize resources more efficiently in order to maintain and operate a robust, economically beneficial transportation network. Through continuous improvement practices, ADOT strives to strategically invest resources to achieve the highest possible return. ADOT also recognizes, in relation to investment and return dynamics, the importance of delivering transportation solutions in a more sustainable manner to achieve economic, social, and environmental goals. ADOT is entering its third year of implementing sustainable strategies into core planning, design, construction, operations, and maintenance activities.

Traditional development and operating approaches, where any given discipline is focused solely on their respective area of expertise, is not always conducive to adopting and/or integrating a collaborative sustainability process. Amongst these challenges, developing a state DOT sustainable transportation program from the ground up, that encompasses an agency wide approach including administration, project planning, design, construction, and systems operations and maintenance, is a particularly daunting effort. Developing a process to operationalize such a far reaching sustainable transportation program, which properly reflects these new and novel economic, social, and environmental considerations as well as maintains executive management buy-in, was experimental at the state DOT level. ADOT presented their initial experience with sustainability tools and process identification through the agency's first ever sustainable transportation annual report in 2015. Since that time, ADOT has made measurable inroads in understanding the sustainability playing field as it encompasses transportation systems, has completed the initial program framework, and initiated subsequent operationalization of these activities.

ADOT realized a series of sustainable implementation milestones in 2015. The two highlights being, moving from implementation to operationalization of the sustainable transportation program itself; and implementation of the third module of the Federal Highway Administration (FHWA) Sustainable Highways Program Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) – the Operations and Maintenance module. ADOT achieved an independently scored platinum rating, scoring 142 points out of a possible 210 points. Other highlights include, the continued use of INVEST to link sustainability and the National Environmental Policy Act (NEPA) on the recently, Fixing America's Surface Transportation Act, or FAST Act, designated Interstate 11 project. ADOT's Excellence in Advancing Sustainable Project Development Award Program is now in its second year. ADOT's Multimodal Planning Division (MPD) is incorporating sustainability into its long range transportation plan outreach efforts in connection with the U.S. DOT's Ladders of Opportunity initiative. Lastly, a host of sustainable transportation specific Every Day Counts

(EDC), State Transportation Innovation Council (STIC), and Accelerated Innovation Deployment (AID) efforts are underway.

For almost 100-years ADOT and its predecessor, the Arizona Highway Department, has planned, designed, constructed, and operated Arizona's transportation system. What ADOT has attempted to do is evolve these time tested processes by encouraging its workforce to work together effectively in an ever-increasing complex world. ADOT's Sustainable Transportation Program is reflective and an extension of this evolution.

Sincerely,

Dallas Hammit

Deputy Director for Transportation and State Engineer

Sincerely,

Steve Boschen

Assistant Director for Infrastructure Delivery and Operations

INTRODUCTION

How is sustainable transportation defined at ADOT?

ADOT Sustainable Transportation Program

Arizona's transportation infrastructure is spread over 114,000 square miles, operates from sea level to 6,000 feet and withstands temperatures that range from below 0°F to over 120°F. Maintaining optimum health and performance of this infrastructure is critical to Arizona's economic vitality, quality of life, and natural and built environments. ADOT recognizes the critical need to plan and prioritize resources more efficiently in order to maintain and operate a robust, economically beneficial transportation network. Through continuous improvement practices, ADOT strives to strategically invest resources to achieve the highest possible return. ADOT also recognizes, in relation to investment and return dynamics, the importance of delivering transportation solutions in a more sustainable manner to achieve economic, social, and environmental goals. ADOT has moved from the early stages of identifying sustainable strategies to operationalizing a sustainable transportation program into core administrative, planning, design, construction, operations and maintenance activities.

ADOT Sustainability Process Identification

The three primary principles of sustainability revolve around achieving an efficient, well-balanced use of economic, social, and environmental resources commonly known as the triple bottom line. In theory, this will allow for proper use of funding while attaining all potential project needs and objectives. A sustainable highway, for example, will not only incorporate the need for mobility and transportation alternatives but also consider safety, accessibility, livability, asset management, and environmental stewardship.

As seen in the figure below, achieving sustainable development may become a challenge, especially on a daily basis. The window of opportunity to fulfill all that is desired before a project's completion requires extensive coordination not only within a core group of individuals delivering the project but also those who are considered stakeholders during the project development process. With multiple driving forces influencing any given transportation project, including fiscal responsibility, ensuring all essential aspects within the context of the project are addressed is ultimately the desired outcome. This requirement to achieve so much with so little will encourage sustainable transportation aspects to be implemented.

As stated in the *Guidebook for Sustainability Performance Measurement for Transportation Agencies*,

> Often, a goal will support more than one principle. Yet no one goal in itself is sufficient to achieve sustainability - it takes multiple goals, pursued in concert, to promote sustainability. When a final set of goals is defined, it's important to crosscheck the package of goals to ensure that all of the principles are well addressed. In doing so, take care not to force-fit the goals to make them map to the principles. A balanced goal set, however, achieves comprehensive coverage of the basic principles of sustainability… *(1)*

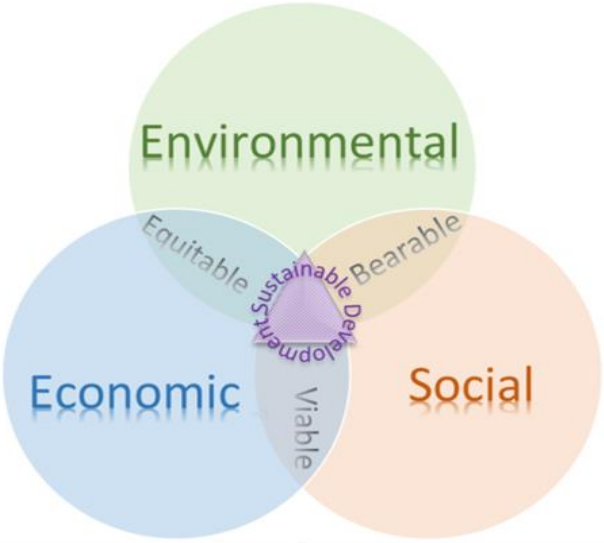

Figure 1. Sustainable development across all disciplines

PART I - OPERATIONALIZING SUSTAINABLE TRANSPORTATION

The 2014 Program Efforts

The FHWA Sustainable Highways Program and the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) Implementation Program have been and continue to be a valuable opportunity for ADOT to acquaint itself with an accessible and comprehensive platform for assessing programs and practices within the agency. FHWA Sustainable Transport & Climate Change Team staff and INVEST have already helped ADOT's Sustainable Transportation Working Group (STWG) to validate strategic decisions, increase knowledge across core functions, and advance a decision-making framework around sustainability best management practices. In 2011 ADOT was a key participant in the INVEST Version 1.0 beta-test program; in 2013 and 2014 ADOT implemented the Project Development module of INVEST, and in 2015 and 2016 scored and is the process of adopting the Operations and Maintenance module of INVEST.

Beyond utilizing FHWA's INVEST, ADOT accomplished a series of sustainable implementation milestones in 2014 and 2015. ADOT's Multimodal Planning Division (MPD) is updating the Metropolitan Planning Organization (MPO)/Council of Governments (COG) Manual further clarifying where our stakeholders may engage ADOT on the topic of sustainability. ADOT increased partnership activities with both the Arizona State University/Julie Ann Wrigley Global Institute of Sustainability and, through transportation sustainability training, our Local Public Agencies. Accelerated Innovation Deployment (AID) Demonstration funding was received and will be used to replace an antiquated lighting system with new light-emitting diode (LED) technology in the historic US 60 Queen Creek Tunnel and the highly travelled I-10 tunnel. In addition, ADOT developed an Excellence in Advancing Sustainable Project Development (EASPD) Award Program. The Agency is looking at 2016 as a prime opportunity to drive a host of new sustainable transportation directives, to further contribute to the national conversation, and to enhance its standing as a state DOT leader in sustainable transportation implementation.

Though many states and local public agencies are encouraging and implementing sustainability plans and/or efforts, integration of an entire sustainable transportation program inside a state DOT can be a particularly complex undertaking. Traditional development and operating approaches, where any given

discipline is focused solely on their respective area of expertise, is not always conducive to adopting and/or integrating a collaborative sustainability process. Amongst these challenges, developing a state DOT sustainable transportation program from the ground up, that encompasses an agency wide approach including administration, project planning, design, construction, and systems operations and maintenance, is a particularly daunting effort. Developing a process to operationalize such a far reaching sustainable transportation program, which properly reflects these new and novel economic, social, and environmental considerations and maintains executive management buy-in, was experimental at the state DOT level. ADOT presented their initial experience with sustainability tools and process identification through the agency's first ever sustainable transportation annual report in 2015. Since that time, ADOT has made measurable inroads in understanding the sustainability playing field as it encompasses transportation systems, has completed the initial program framework, and initiated subsequent operationalization of these activities.

Building on the 2014 Program Efforts

The most effective use of resources in this day and age is one in which multiple objectives are achieved, and the methods which lead to those outcomes are documentable and repeatable. To achieve a documentable and repeatable objective, a difficult process must first take place – one of compromise. The meticulous process of identifying and prioritizing what is the reasonable universe of sustainable considerations that are applicable to a given DOT is a discussion that ADOT benefited from inception. Just as important was the participation of executive management in said conversation. This subsequent support aided in establishing the beginnings for the development of ADOT's Sustainable Transportation Program. Having champions frame the variables ahead of time resulted in a more focused, thoughtful, and strategic discussion with executive management and safeguarded a successful outcome.

As stated by Garrett Hardin in his 1968 address to the American Association for the Advancement of Science - *The Tragedy of the Commons*,

> The compromise achieved depends on a natural weighting of the values of the variables. It is when hidden decisions are made explicit that the argument begins. The problem for the years ahead is to work out an acceptable theory of weighting. Synergistic effects, nonlinear variation, and difficulties in discounting the future make the intellectual problem difficult, but not (in principle) insoluble *(2)*.

ADOT's continued success to date was facilitated by the introduction of a systematic process in the early stages of the sustainability program development. ADOT initially developed a Milestones Framework, consisting of thirteen (13) milestones. This aided in the sustainable transportation building process and drove the topic's introduction inside the state DOT. A working group developed this framework with the goal of simultaneously creating the subsequent Operational Focus Areas (OFAs), consisting of thirty-seven (37) reasonable entry points to implement the entire program. The Milestones Framework was developed through extensive and thoughtful discussion about the aforementioned prioritization, weighting, and reasonableness of the previously discussed variables process. The implementation of the Milestones Framework was conducted and completed January 2013-June 2015.

ADOT Sustainable Transportation Program Milestones Framework

Figure 2. The thirteen (13) milestones accomplished during January 2013 – June 2015
Final milestone achieved June 2015 with the release of ADOT's first annual Sustainability Report

A champion is an individual who is instrumental in garnering interest and support. The ADOT effort benefited from the following skill sets to reach the **Champion(s)** milestone - an understanding of global sustainability, public agency resource management experience, transportation construction program project delivery, project management support and knowledge basis, grant-leveraging capabilities, and consensus building. These same technical skills were also the catalyst for reaching the Universe of Variables and Executive Management milestones. Executive management has commented that without the two individuals championing this effort the program might not even exist.

It is appropriate to briefly discuss what encompassed the **Universe of Variables** milestone and the basic process for inclusion and exclusion of what would be considered key to developing the program. The process was achieved conducting two activities. The first activity involved the "review of sustainability rating systems that have been widely accepted as a way of quantifying how sustainable construction projects are . . . [a] method that can be used to improve the consistency through group decision making. Instead of using a single representative from the DOT, a group of persons who have the authority to make sustainable decisions could participate" (3). The second activity centered on internal engineering and

technical outreach. What the working group referred to as the extrication step. This step was developed to address the need to delve into the ADOT engineering and technical spectrum which often exists in silos. The extrication step ensured ADOT's existing knowledge base was accessed and, more importantly, ensured the dynamic individuals with this knowledge base were included in the project. The initial effort included mainly individuals or teams comprised of civil engineers from ADOT's Statewide Project Management team and environmental planners from ADOT's Environmental Planning. It quickly became apparent that a new and novel collaboration process had materialized. This collaboration effort developed a unique perspective centered on applying the tools and themes that encompass the project development process.

Although the ADOT Sustainable Transportation Program Milestones Framework shows the process began with a goal and a champion(s), it is notable to recognize the extensive actions and documents in existence prior to framing these efforts. It is equally important to recognize ADOT was already embracing the importance of delivering transportation solutions in a more sustainable manner to achieve economic, social, and environmental goals. These early efforts, though contributory, had not sustained a consistent level of momentum or achieved program wide adoption. The ADOT internal themes of complete transportation, while keeping in mind the importance of planning, developing, and maintaining a system for the public good, have had a long standing tradition within the agency; however, the objective, in this instance, would solidify remaining opportunities and ensure substantial progression toward more inventive sustainable deliverables for the future project development process.

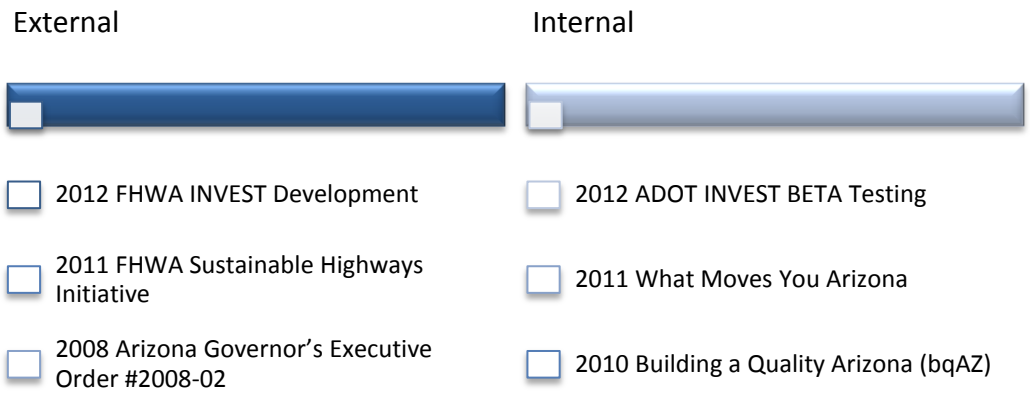

Figure 3. Existing Actions and Documents (3)

The Remaining eleven (11) milestones are briefly discussed below:

Executive Management

The root of ADOT's efforts to go above and beyond stems from the agency's executive management partnering and outreach efforts. With two dozen recognized tribes, countless local, state, and federal stakeholders including but not limited to the Arizona Department of Water Quality, the National Forest Service, and the Bureau of Land Management, ADOT has long had to consider a tremendous amount of perspectives. Executive management has generally operationalized this effort through project partnering meetings and context sensitive solutions (CSS). The maturity of these CSS processes and communication endeavors greatly enhanced the probability of support for a sustainable transportation program.

A prime example of extensive CSS outreach can be seen in ADOT's rehabilitation of State Route (SR) 179. ADOT used an innovative approach called a needs-based implementation plan (NBIP) to strategize improvements along SR 179. ADOT continuously solicited input from the community through advisory panels, focus groups, workshops, charrettes and other techniques. The NBIP took a CSS approach by balancing safety and mobility with scenic, aesthetic, historic, environmental and other community values. The NBIP was structured around charrettes open to all: first, a planning charrette in which residents stated their core values and vision for the corridor, and second, a gaming workshop giving residents an opportunity to build their role using a tool kit of design elements. At two screening workshops and a third charrette, the community viewed twelve planning concepts to produce a single preferred plan for a greatly improved two-lane road designed for maximum context-sensitivity through Sedona, the Village of Oak Creek and a portion of a highly sensitive area within Coconino National Forest. For further details involving this project, see the FHWA CSS.org case study *(4)*.

Major beneficial outcomes resulting from the reconstructed road were a much safer route, more reliable/predictable travel times between I-17 and Sedona, and a decreased possibility of closures due to crashed and/or other incidents. It enhanced the visual and scenic quality of the driving experience and offers pullouts for scenic viewing. It is now more accessible to a variety of users and much more easily utilized by cyclists and pedestrians. The roadway provides safe access for transit users and improved access to nearby trails. Also, the project has brought together agencies and stakeholders who are more likely to collaborate in the future. The All-American Road status that was obtained through this effort enhances the reputation of the community and provided an incentive for preservation. It is a tremendous source of pride for the entire community and facilitated a boom in tourism, which is the mainstay of the Sedona area's economy *(4)*.

FHWA Support/INVEST

ADOT has always attempted to foster a positive working relationship with both the FHWA Arizona Division and the FHWA national offices. From the onset of building a sustainable transportation partnership with FHWA and implementing, and promoting sustainable transportation, INVEST was centered at the core of the Milestones Framework. This partnership has contributed significantly to the national state of practice on measuring and advancing the sustainability of transportation projects and programs.

As a pilot test agency for these activities, ADOT contributed valuable feedback that assisted FHWA in institutionalizing INVEST within state DOT arenas and improved the tool for releases of INVEST v1.0. v1.1, and v1.2. ADOT's application of the INVEST Project Development (PD) module to score and improve the sustainability of fifty (50) construction projects provided an excellent example to be shared nationally. The ADOT scoring approach may be used to outline how other transportation entities could utilize the online

tool to measure sustainability through the review of criteria which aid in improved economic, social, and environmental outcomes at both the project and programmatic levels. ADOT's training workshops with internal stakeholders and local governments also provided a great example of how INVEST can be used as a collaboration tool to advance a decision-making framework around sustainability best management practices. With all this work, the FHWA and ADOT relationship has pushed sustainable transportation forward at the national level and improved how all three modules of INVEST cover the full life cycle of transportation projects and programs.

Establishing of the Sustainable Transportation Working Group (STWG)

The STWG was formed to serve as a technical advisory body having started inside ADOT's Multimodal Planning Division and Environmental Planning areas. The champion(s) drew upon contacts within these groups to initiate the January 2013 FHWA INVEST grant process. As part of the further 2014 STWG solidification and the Milestones Framework development, one additional champion materialized that measurably influenced the speed at which the program matured. Several individuals, loosely connected by interest, partnered together with the champions to form the current working group participants. Three larger influences have attributed recognition for the maturity of the working group, FHWA Office of Sustainable Transport and Climate Change, the FHWA Arizona Division Office, and ADOT's State Engineer Office. In 2015, the working group loosely included thirty participants from many fields, including federal and state managers, district representatives, engineers, and planners.

Initial INVEST PD Rollout

The key to ADOT's INVEST PD scoring methodology was the assumption that traditional project development could be scored through the INVEST sustainable PD criteria. ADOT was particularly encouraged with the methodology since the tool was vetted and beta tested using such a large number of national practitioners. Once that assumption was established, the project team reviewed through pre-scoring training, technical group project scoring, and individual scoring of key entry points to examine the ADOT PD process and the INVEST PD criteria. As it turned out this process and approach was relatively seamless and reflected how even INVEST could be easily adopted into a transportation setting.

Overall, the ADOT methodology attempted to establish and understand what the project team viewed as three separate levels: standard design and PD processes, current best management practices, and new sustainable objectives – aka where efforts went above and beyond. This methodology created a platform for multiple users to assess their sustainability efforts under one recognized approach. The tool was evaluated in terms of both how the criteria would apply to a variety of development projects specifically the installation of new roundabouts, as well as, where the tool would be best housed within a department of transportation at the state and/or local government level. Through the use of this method, ADOT was able to establish the full extent of the PD module and normalize how INVEST would be utilized.

Scores of the fifty (50) projects (5)

Gold	2	4% of the projects rated gold
Silver	9	18% of the projects rated silver
Bronze	20	40% of the projects rated bronze
Not Rated	19	38% of the projects not rated

ADOT State Engineer's Office (SEO) Activity Briefings

In order to introduce, inform, and educate ADOT's current executive leadership initially regarding goals of launching the sustainability efforts and subsequently about the ongoing integration process, the champion(s) introduced the idea of providing a monthly update to the SEO. This update was proposed to take the form of an activity journal consisting of a two-page document. The journal had to, in its brevity, outline the challenges and opportunities that these new efforts would encounter, leverage the time the briefing would be in front of executive management, and be sensitive to introducing new concepts into legacy state DOT operating dynamics. The project team was fortunate to have a responsive SEO, who met one on one to discuss the first two monthly submittals. Thus, ensuring the product served its intent, yet remained a quality quick reference document for decision makers.

The activity journals also attempted to be a communication tool between technical, scientific staff working on the projects and the decision makers at ADOT. The format for the documents, which has evolved over the eighteen months of its use, are individually tailored to both update ongoing multi-month efforts and serve as an announcement forum for new directions and projects. It has been especially useful as an outline for the quarterly, in-person State Engineer's Office meetings. In conjunction with the monthly journals and the quarterly in person updates, this process has afforded the STWG opportunities to build a format to update all senior program managers through what is referred to as the Future Focus Meetings – an ADOT quarterly meeting of the senior group managers, District Engineers, and the State Engineer's Office.

Design Excellence Award Program

The Excellence in Advancing Sustainable Project Development Award Program (EASPD) was approved by the State Engineer's Office in the fall of 2014. A pilot effort was undertaken during fiscal year 2015 resulting in two projects earning the award. The first pilot award was presented by the State Engineer's Office to the Prescott District for the State Route 89 & Perkinsville Road Roundabout Project - 089 YV 329 H8330 01C. The second pilot award was presented to the Statewide Project Management Group for the $60 million Phoenix – Globe Highway (US 60) Silver King Section & Superior Streets Project - 060 PN 222 H7900 01C. Both these projects were highlighted in ADOT's nationally released June 2015 Sustainability Report.

The award is a new sustainable project development award program for the ADOT districts and project development groups. The introduction of a merits based award program has increased the drive and competition between districts and project managers to achieve more with less, which in turn nurtures an atmosphere for innovative sustainable design and construction.

The award developed as follows:

- Award program approved September 2014
- Award committee established 2015
- Standardized ADOT/INVEST Score methodology established to support award in 2015

Methodology

- INVEST Score 40%
- Best Management Practices (above and beyond) 40%
- Collaborative Efforts 20%

- Quarterly meeting held to approve award recipient

Internal/LPA/MPO/COG Collaboration

The collaboration aspect of the process sparked new natures of discussion which ultimately led to all the individuals involved learning more about various aspects of the development process. This type of learning opportunity is and will continue to be essential in ensuring project delivery in a consistent and timely manner. Further development of the scoring criteria and how those questions are sequenced in INVEST v1.2 should further ensure the ultimate goal of implementing the program and allow for a more flexible applicability. INVEST was well received during ADOT's internal training of the tool, as well as, in the on-location training opportunities. The application was able to enumerate current best management practices and existing sustainable behaviors. It provided a discussion based review of multiple layers of disciplines required for the completion of any project. This allowed for the individuals involved to view the breadth and depth of knowledge required by their peers to preform daily tasks. Because of this internal success, the STWG reached out to Local Public Agencies, MPOs, and COGs to gage their interest in conducting sustainable transportation training sessions. The vital aspect of these sessions and the use of INVEST as a foundation was how it sparked innovative thought processes for those new to the topic, and challenged traditional continuous improvement approaches. ADOT was able to relay the internal benefits gained to these outside entities. INVEST was irrefutably acknowledged as a beneficial tool which may continue to broaden lines of discussion, facilitate essential communication, and lead to further modernization of design.

Develop Case Studies

As part of the grants that were received from FHWA to conduct some of these activities, ADOT committed to producing sustainable transportation case studies as some of the deliverables. These case studies served to highlight activities that were particularly noteworthy in the depth and breadth of achievement. The STWG took the opportunity to develop two case studies, one covering the EASPD Award Program and the second covered the positive aspects of partnering with one of our local public agencies in the use of sustainability scoring tools. Additionally ADOT, supported by the FHWA partnership, desired to further advance this milestone by incorporating additional subsequent case studies in order to expand the available information on the Sustainable Highway Initiative's website.

National Conferences

ADOT's 2014, 2015, and 2016 national conference and webinar participation allowed two outcomes for the program. The first outcome was access to other national and international points of contact in the fledgling area of sustainable transportation. The second outcome was uniquely beneficial to building such new and novel program inside a state DOT. By simply being asked to participate in an ever growing array of platforms, the acceptance and resulting confidence that ADOT's program received reinforced ADOT was on the right track. The culmination of these participations resulted in speaking and knowledge sharing

contribution at the 2015 Transportation Research Board (TRB) Annual Meeting and the TRB Transportation for Sustainability – An International Conference.

Relevant University Links

The Julie Ann Wrigley Global Institute of Sustainability is the hub of Arizona State University's sustainability initiatives. The ASU Wrigley Institute advances research, education, and business practices for an urbanizing world. It's School of Sustainability, the first of its kind in the U.S., offers transdisciplinary degree programs focused on finding practical solutions to environmental, economic, and social challenges. ADOT was interested in gauging the program progress against other recognized sustainability focused bodies.

The Mission of the ASU Wrigley Institute is to:

- Articulate and exemplify Arizona State University's university-wide commitment to sustainability
- Actively support and encourage Arizona State University units and their partners in the teaching, learning, and discovery of sustainability
- Implement, extend, share and promote sustainable practices locally, nationally, and globally
- Connect scientists, scholars, humanists, engineers, technologists, policymakers, business leaders, students and communities to enhance the capacity to address challenges of sustainability

Julie Ann Wrigley Global Institute of Sustainability/Arizona State University (6)

As part of ADOT's INVEST PD grant effort, the project team developed a pilot university outreach effort. This initial effort took the form of a joint case study project in connection with the School of Sustainability and the Julie Ann Wrigley Global Institute of Sustainability both housed at Arizona State University. In the fall of 2014, the school held their Urban Sustainability: Best Practices/Case Studies graduate class. ADOT sought to achieve three goals: deepen the topic of transportation at the university programs level, formalize transportation and sustainability linkages at the university level, and introduce the interesting technical and scientific puzzles found in state DOT program to students.

First Annual Sustainability Report

According to Bloomberg Bureau of National Affairs, Transportation/Environment News Alert titled, *Arizona DOT Releases Final Report on Impacts of INVEST*, "[t]he Arizona Department of Transportation has released a final evaluation of the use and effectiveness of the Federal Highway Administration's INVEST sustainability planning tool in the state's transportation efforts. The web-based tool provides measurable criteria for practitioners to implement and use to evaluate transportation initiatives' sustainability through system planning, project development and operations and maintenance. Arizona has implemented the operation and maintenance module for 2015 as part of the development of the Intermodal Transportation Division sustainability program" *(7).* These types of accolades further validated the program's efforts but more importantly led to a national leadership role for ADOT on these topics allowing previously unavailable exposure to other state DOT best practices.

Beyond the Thirteen (13) Milestones - Operationalization Process Framework June 2015 - December 2015

Mentioned prior, the second portion of the sustainable program development initiative was to simultaneously progress the subsequent roadmap in order to operationalize the entire program within the

agency. The lessons learned through the thirteen (13) ADOT Sustainable Transportation Program Framework Milestones allowed a much easier transition to the development of Operational Focus Areas (OFAs) which consisted of thirty-seven (37) reasonable entry points. The same STWG members were relied on to contribute their technical expertise in order to identify the likeliest candidate projects and activities that could both be completed but also secure the program's needed victories to support wider acceptance.

The following OFAs identify those candidate projects and activities that cumulatively reflected the program's action items. The opportunities were chosen for one or all of three reasons: because there was a true operational need, because it aligned with the agency's Strategic Focus Areas (SFAs) (ADOT's agency mission), and/or because it could contribute to both Arizona and the national state of the practice in connection to sustainable transportation.

To further support similarly aligned federal initiatives, the OFA format was loosely modeled on the key dimensions of capability found in the 2012, *Creating an Effective Program to Advance Transportation System Management and Operations* (TSMO) Primer. The STWG determined that aligning the sustainable transportation program goals with another fast growing FHWA initiative would further smooth adoption. That document "shows that moving beyond a collection of ad hoc strategy applications to an effective TSMO program is dependent on deliberate change management to improve agency capabilities . . . so that agencies can identify their current areas of strength and weakness" *(8).*

The ADOT Sustainable Transportation Program started out 2016 by putting out a revised sustainability consideration list that aligned with INVEST 1.2, a call out for Design Excellence Award Program candidates, and a list of ten key program focus areas:

1) LED/Solar lighting

2) Alternative pavement types

3) Consideration of freight mobility

4) Use of EDC initiatives – GRS-IBS and ultra-high performance concrete

5) Use of accelerated construction technics

6) Post construction BMP installation

7) Introduction of multimodal path ways, bike or pedestrian connections or safety measures (Complete Transportation Guidebook for reference)

8) Integration of modeling technics to determine least damaging most practical design relative to the surrounding environmental constraints

9) Consideration of alternate materials with intent of end of life reuse advantages

10) Exceptional example of stakeholder involvement and compromise

Two longer term initiatives are also being undertaken in 2016. The first is working with ADOT's Administrative Services Division for the development of relevant agency sustainability policies. Several of these proposed policies are identified in the recommendation section at the end of this report and draft versions are additionally available in the appendix.

Secondly, on a much larger scale, was the September 2015 development of an ADOT Resilience Pilot Program which will reside within ADOT as a Sustainable Transportation subprogram. ADOT's mission to provide a safe, efficient, cost effective transportation system can be compromised from the effects of heat extremes, dust storms, wildfires, flooding, landslides, rockfall incidents, and slope failures. In order to cope with the ever-growing cost of these threats, ADOT set out to develop a pilot resilience program that could incorporate existing planning, design, construction, operations, and maintenance criteria, identify a strategic and systematic framework, take advantage of available technologies, tools, and partnerships, build upon their 2014 *Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona* and the 2015 *Extreme Weather Vulnerability Assessment Final Report*, and contribute to the national conversation surrounding these topics. Since ADOT has had a long history considering the balance between predictable asset deterioration curves and the unknown, erratic, and abrupt incidents of flood, overtopping, system hotspots, hydraulic-related failure, and extreme weather impacts, these topics were identified to make up the core of the pilot program. A separate report to be issued shortly will discuss the three framework components of ADOT's Resilience Pilot Program - stormwater, extreme weather, and handling scientifically-informed climate data downscaling as it relates to transportation systems. Moreover, this new program aligns with the resilience additions to INVEST 1.2, represents the partnerships undertaken to further evidence-based decision making through the opportunities from next generation ground based LiDAR (Light Detection and Ranging), drone-based photogrammetry services, and data collection platforms that can advance magnitude of peak flow engineering efforts, and further develop sustainable stormwater management approaches.

The next three pages reflect the previously mentioned OFAs, wider outcomes from the program efforts, and the references for the first half of this report.

Figure 4. 2016 Operational Focus Areas (3)

Sustainable Transportation Planning

- MPD/MPO/COG sustainability tools training
- I-11 Intermountain West Corridor Tier1 EIS INVEST use
- SR410 Sonoran Corridor Tier1 EIS INVEST use
- ADOT MPD/MPO/COG Guidebook Update
- Complete Transportation Guidebook - 2016 New
- Sustainable outreach with Arizona Tribes

Sustainable Transportation Project Development

- EASPD Award Program
- Continue INVEST PD scoring
- Sustainable Earthwork Plan
- Sustainable Pavement System Pilot Program
- Upgrade Standard Specifications - waste
- Upgrade Standard Specifications - LED lighting
- Upgrade Standard Specifications - HDPE Pipe
- Project scoping documents
- FHWA Every Day Counts GRS-IBS Technology adoption

Sustainable Transportation Operations

- US DOT Office of Operations TSMO climate guidebook
- ADOT incorporation of TSMO activities
- FHWA Arizona Division Office actvities
- Steward solar powered weigh-in-motion truck projects
- High friction surface treatment use
- TSMO case studies to advance national conversation

Sustainable Transportation Maintenance

- INVEST OM Scoring Project - This report
- District Sustainability Working sub-group
- PeCoS maintenance performance system upgrades
- Millings reuse policy development
- Leverage the heavy equipment idling policy
- Leverage equipment services fuel efficiency plan
- Final Report INVEST OM 2016
- Tie OM to performance measures and TAMP

Sustainable Transportation Agency

- Comprehensive Internal Sustainability Plan
- Provide support for alternative fuel vehicles
- Consolidated energy efficiency and use plan
- Consolidated recycling plan
- Expand university outreach
- Begin sustainable freight subprogram
- Continue to link to key commerce corridors
- Maintain national leadership role
- Assist FHWA, AASHTO, TRB in framing global sustainable tranport

Figure 5. Summary of Wider Outcomes Achieved Through the Framework and OFAs

INVEST Direct	ADOT Statewide Project Management training
	ADOT Environmental Planning Group training
	Arizona Local Public Agency outreach training
	Arizona Local Public Agency outreach training
	Score fifty (50) ADOT construction program projects
	ADOT & sustainability improved understanding
	State DOT national leadership opportunity
	ADOT INVEST grant #1 final report – June 2015
	ADOT MPD INVEST System Planning (SP) reintroduction
	ADOT INVEST grant #2 Operation & Maintenance (OM) introduction

INVEST Indirect	ADOT State Engineer's Office monthly activity briefings
	Local Public Agency partnering tool
	ADOT INVEST PD case studies
	State university outreach development
	Wider proliferation (Design, Roadway, District, and other State DOT sharing)
	ADOT/USGS partnership development on stormwater issues
	ADOT Excellence Award Program
	ADOT Best Management Practices
	FHWA, State DOT, International state of the practice
	Changes in urban transport - U.S. DOT *Beyond Traffic* and *Smart City Challenge*
	Layer in key activities – TRB 1st international sustainability conference
	United Nations - Sustainable Development Goals (SDGs)
	Climate, extreme weather and resilience
	Transportation asset management

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[3] Olmsted, S., Lester E. *The Collaborative Benefits of Using FHWA's INVEST - A State Department of Transportation Sustainability Implementation Case Study*. Paper for presentation, TRB Annual Meeting, Pres. # 15-4262. January 2015.

[4] Arizona Department of Transportation / City of Sedona, Arizona Local Government INVEST Training and Scoring. Training conducted by Olmsted, S., Lester, E. May, 2014. And excerpts from the SR 179 CSS.org case study. http://contextsensitivesolutions.org/content/case_studies/sr_179__village_of_oak_creek_to/

[5] Olmsted, S., Lester E. *The Collaborative Benefits of Using FHWA's INVEST – Arizona Department of Transportation Sustainability Implementation Final Report*, P.36. June 2015. https://www.sustainablehighways.org/779/40/Arizona_DOT_-_Using_INVEST_to_Integrate_Sustainability.html

[6] Olmsted, S., Lester E. *The Collaborative Benefits of Using FHWA's INVEST – Arizona Department of Transportation Sustainability Implementation Final Report*, P.41 June 2015. https://www.sustainablehighways.org/779/40/Arizona_DOT_-_Using_INVEST_to_Integrate_Sustainability.html

[7] Bloomberg Bureau of National Affairs, Transportation/Environment News Alert titled, *Arizona DOT Releases Final Report on Impacts of INVEST*, Volume 17, Issue No. 44, Jun 26, 2015

[8] FHWA. *Creating an Effective Program to Advance Transportation System Management and Operations*, P.1. 2012.

FIGURES

[1] Lester, E. Customized diagram based on INVEST application. November 2014.
[2] Olmsted, S., Lester E. Customized diagram ADOT sustainable milestones. November 2015.
[3] Olmsted, S. Customized diagram. November 2015.
[4] Lester, E., Olmsted, S. Customized OFAs diagram. November 2015.
[5] Olmsted, S. Customized diagram. November 2015.

PART II - FHWA's INVEST OPERATIONS & MAINTENANCE IMPLEMENTATION

A 2015/2016 INVEST Grant Project between ADOT, ADOT Sustainable Transportation Program Team, FHWA Arizona Division Office, and FHWA Sustainable Transport and Climate Change Team

Complexity of developing a State DOT Sustainable Transportation Program

ADOT has initiated a comprehensive Sustainable Transportation Program, comprising several milestones which run the gamut from recognizing and rewarding exemplary sustainable actions within ADOT to building local partnerships, creating linkages to the academic community, and contributing to the ongoing national dialogue on transportation sustainability. A core element of this platform is continuing to partner with FHWA to test, improve, promote, and use the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST).

The Federal Highway Administration (FHWA) developed INVEST to aid transportation agencies in integrating environmental, economic, and social sustainability objectives into programs and projects. The tool, which as stated in its name is voluntary, scores agencies based on adherence to a set of best practices across different disciplines. It includes four modules: Systems Planning (SPS and SPR), Project Development (PD), and Operations and Maintenance (OM). The SPS, SPR, and OM modules are intended for evaluating an agency's programs and the PD module is for the evaluation of projects, from early project planning through construction. Each module is independent and is evaluated separately. The PD module consists of multiple scorecards designed to recognize the varying scope, scale, and context of projects across the country. This report focuses solely on the OM module.

As part of a pilot application, ADOT conducted scoring workshops for the 14 sustainability criteria constituting the OM module. The criteria, which are detailed subsequently, cover both internal operations and infrastructure operations and maintenance. For each criterion, the ADOT project team facilitated discussions with relevant ADOT subject matter experts. Generally, the dozens of participants were the most senior practitioners within their respective subject areas. The discussions—most of which were held in person at ADOT Headquarters in Phoenix—involved from one to five participants and typically required one hour.

This report summarizes the estimated scores for each criterion, based on the aforementioned discussions and includes brief scoring explanations. ADOT achieved an independently scored 142 points out of a possible 210—sufficient to achieve Platinum status, INVEST's highest rating. The exercise further strengthened ADOT's understanding of sustainability best practices and helped identify opportunities for improvement.

This report also summarizes resulting recommendations aimed at further enhancing the sustainability of ADOT's OM activities and provides suggestions to FHWA for enhancing and improving INVEST, which is an evolving tool.

This INVEST OM implementation builds on previous engagement with both the Project Development and System Planning modules. Throughout the assessment of the tool, ADOT was able to expand its knowledge of current and evolving sustainability best practices, identify opportunities for improvement, and foster intra-agency collaboration.

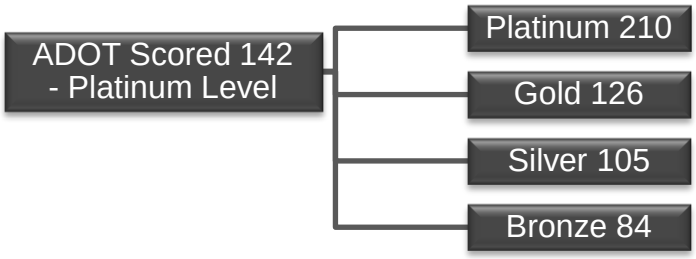


Figure 1. Number represents the maximum for that category

INVEST Overview[i]

INVEST System Planning

The System Planning for States (SPS) module provides criteria to self-evaluate system-level planning and programming policies, processes, procedures and practices. The SPS module is geared towards States, Tollways and local agencies that perform landscape-scale and corridor-wide planning and that typically own infrastructure.

The System Planning for Regions (SPR) module provides criteria to self-evaluate system-level planning and programming policies, processes, procedures and practices. The SPR module is geared towards Metropolitan Planning Organizations, Council of Governments, or other planning organizations that perform landscape-scale planning for a regional area (and that typically do not own infrastructure).

INVEST Project Development

Project Development (PD) is the second step in the lifecycle of a transportation project. This is where specific projects conceptualized and programmed in the System Planning processes are planned, designed and constructed. The Project Development module includes criteria that span the entire project development process from early planning, alternatives analysis, environmental documentation, preliminary and final design, and construction.

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network.

INVEST Version 1.2 Summary of Revisions[ii]

After launching INVEST Version 1.0, FHWA underwent a process of soliciting feedback from users from States, MPOs, Local Agencies, Federal Lands, and more. Each of the comments received was thoroughly reviewed and modifications to the INVEST framework, criteria, and online tool were made in response. The release of Version 1.1 in January 2015 introduced minor edits, formatting changes, and tool enhancements that did not affect scoring criteria.

With the release of Version 1.2, FHWA completes the responses to comments that required more substantial changes. Version 1.2 includes significant changes to criteria, scorecards, modules, and scoring in INVEST (Click here to view a Matrix of INVEST Version 1.2 Criteria Changes). This list below describe the major changes that were made, and the last few expanding questions describe the transition to Version 1.2, and what that means for project and program evaluations already underway:

1.0 System Planning has been replaced by "System Planning for States" and "System Planning for Regions."

2.0 A bonus Innovative Criterion has been added.

3.0 Five new criteria, IN-01: Innovative Criterion, PD-30: Low Impact Development, PD-31: Infrastructure Resiliency Planning and Design, PD-32: Light Pollution, PD-33: Noise Abatement has been added to the PD module, and one criterion has been removed.

4.0 Existing criteria and scoring modification have been modified throughout the tool.

5.0 A Resources Section has been added to the Criteria Write-ups.

6.0 Links to Case Studies and Criterion Examples have been added to the Online Criteria Write-ups.

7.0 A new guide, called Using INVEST to Accomplish your Goals, has been added.

8.0 The website has been reorganized and tabs have been renamed to aid in navigation.

9.0 A Recreational and Scenic scorecard has been added.

10.0 User interface and website tool enhancements have been launched.

11.0 The Website Transitioned to Version 1.2 on September 14th.

12.0 All New Project and Program Evaluations will be in Version 1.2 of INVEST.

13.0 Translation of Existing Evaluations to Version 1.2 is optional.

14.0 A Read More About INVEST section has been developed.

The new bonus Innovative Criterion allows users extensive flexibility to identify unique efforts to their respective operations. Specifically:

- Up to three Innovative Criteria, IN-01 through IN-03, have been added per scorecard for each of the four modules (SPR, SPS, PD and OM). The Innovative Criteria allow users to define sustainable innovations and emerging technologies that they have addressed that are not included in INVEST in order to earn credit for these innovations. The credits earned for using Innovative Criterion are bonus points earned because no points are included in the total number of points achievable for this criterion.

- Organizations desiring to use the Innovative Criteria will fill out a form and a template for a new criterion on their topic. The form requests basic information, confirms the topic is not already included in INVEST, and confirms that it goes above and beyond regulations and the standard practice of care. This is submitted to FHWA for a quick review, and will be added to the project or program scorecard if and when concurrence by FHWA is obtained. The examples submitted will also be available to share under the new RESOURCES tab on the website.

- For each module, the number of Innovations, Points per Innovation, and the Maximum Total of Points Earned from Innovative Criteria is limited per the following table:

	SPR Module	SPS Module	PD Module	OM Module
Max. Points/Innovation	5	5	3	5
Max. Innovations/Scorecard	3	3	3	3
Max. Points/All Innovations	10	10	6	10

Figure 2. INVEST's New Innovation Criteria Points

ADOT and INVEST

Through its partnership with FHWA, ADOT has endeavored to contribute significantly to the national state of practice in the field of transportation sustainability and sustainability performance measurement. In 2012, ADOT participated in an INVEST System Planning (SP) beta test, offering feedback to improve the tool for subsequent iterations of INVEST. In 2014, ADOT applied the INVEST Project Development (PD) module to score and improve the sustainability of fifty (50) construction projects, providing a proof of concept of how INVEST can help agencies improve economic, social, and environmental outcomes at both the project and programmatic levels. ADOT's training workshops with internal stakeholders and local governments also demonstrated how INVEST can be used collaboratively to advance sustainability best practices. With the OM pilot (documented in this report), ADOT has worked with all three modules of INVEST, covering the full life cycle of transportation projects and programs.

ADOT conversion from INVEST v1.1 to v1.2[iii]

ADOT went the extra step to assess the change in OM scoring since the bulk of our consultant led scoring effort was mid-2015 prior to the v1.2 rollout. The flexibility built into the INVEST tool, and in this case the OM Module, allowed ADOT to easily review the criteria changes and additions in relation to the

summer/fall 2015 scoring exercise. Extensive notes and scoring information were gathered during the technical sessions allowing for the ADOT scoring team to easily assess the following INVEST scoring modifications to the platinum score of 142. The following criteria notes reflect how the conversion to INVEST v1.2 would have impacted ADOT. The scoring change was nominal and would have resulted in a revised OM score of 145.

ADOT INVEST v1.2 Conversion Impacts

Criteria	Scoring Modification	ADOT Impact
OM-1 Internal Sustainability Plan	Clarifies scoring of OM-01.6	No Change
OM-02: Electrical Energy Efficiency and Use	Makes OM-02.5b dependent on OM-02.5a	No Change
OM-03: Vehicle Fuel Efficiency and Use	Clarifies scoring options for OM-03.1	No Change
OM-04: Reduce, Reuse and Recycle	Add 'Reduce', Reuse and Recycle	No Change
OM-05: Safety Management	Clarifies OM-05.3	No Change
OM-07: Pavement Management System	Clarifies OM-07.1/OM-07.2a	No Change
OM-08: Bridge Management System	Clarifies scoring of OM-08.2b	No Change
OM-10: Hwy Infra Preservation/Maintenance	Deletes, Renumbers, Adds	No Change
OM-12: Road Weather Management Program	Revise, Adds, Clarifies, Changes	**Added 3 Points**
OM-13: Transportation Mngmt and Ops	Revise, Adds, Clarifies, Changes	No Change
OM-14: Work Zone Traffic Control	OM-14.5 includes dis-incentives	No Change

Summary of ADOT INVEST OM v1.1 Scoring Results

Operations & Maintenance Criteria by Sustainability Principle			
	Triple Bottom Line Principles		
Criterion Number and Title	Social	Environmental	Economic
OM-01: Internal Sustainability Plan	x	x	x
OM-02: Electrical Energy Efficiency and Use		x	x
OM-03: Vehicle Fuel Efficiency and Use	x	x	x
OM-04: Reduce, Reuse and Recycle		x	x
OM-05: Safety Management	x		x
OM-06: Environmental Commitments Tracking System	x	x	
OM-07: Pavement Management System		x	x
OM-08: Bridge Management System		x	x
OM-09: Maintenance Management System	x	x	x
OM-10: Highway Infrastructure Preservation and Maintenance	x	x	x
OM-11: Traffic Control Infrastructure Maintenance	x	x	x
OM-12: Road Weather Management Program	x	x	x
OM-13: Transportation Management and Operations	x	x	x
OM-14: Work Zone Traffic Control	x	x	x

Figure 3. INVEST v1.2 OM Module comprises 14 criteria

Complete fulfillment of all of the suggested measures grouped within a given criterion would result in a score of 15 points—with various degrees of partial credit awarded—with a total of 210 possible points. FHWA created four levels of achievement, which can be used within an agency to highlight improvement needs and to track progress toward more sustainable practices over time. Bronze, the lowest tier of recognition, is attained by achieving at least 30% of total points possible (63 points), with subsequent levels designated as Silver (40%/84 points), Gold (50%/105 points), and Platinum (60%/126)—the highest level of achievement. With a calculated score of 142, ADOT receives a Platinum rating for its OM practices—although areas for improvement remain.

The scoring breakdown in presented in Figures 4 and 5, below. ADOT received scores of 13 or higher on 7 of 14 criteria (and perfect scores on 4 criteria), and received fewer than half of the points possible on 4 criteria. One module, Environmental Commitments Tracking System, received a score of zero.

Achievement Level	% Total Points Possible	Points Required
ADOT	68%	142
Platinum	60%	126
Gold	50%	105
Silver	40%	84
Bronze	30%	63

Figure 4. INVEST Achievement Levels - Source FHWA

Criterion	Title	Score
OM-1	Internal Sustainability Plan	4
OM-2	Electrical Energy Efficiency and Use	8
OM-3	Vehicle Fuel Efficiency and Use	15
OM-4	Reuse and Recycle	13
OM-5	Safety Management	13
OM-6	Environmental Commitments Tracking System	0
OM-7	Pavement Management System	15
OM-8	Bridge Management System	7
OM-9	Maintenance Management System	9
OM-10	Highway Infrastructure Preservation and Maintenance	13
OM-11	Traffic Control Infrastructure Maintenance	9
OM-12	Road Weather Management Program	6
OM-13	Transportation Management and Operations	15
OM-14	Work Zone Traffic Control	15
Total		142 Platinum

Figure 5. INVEST OM Module Scores by Criteria

The summary findings for each of the INVEST OM criteria are presented in the next section.

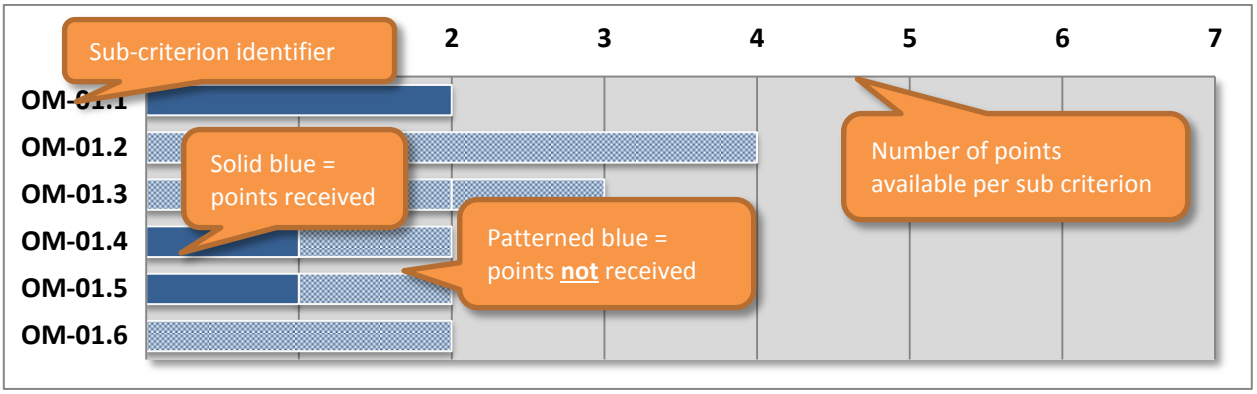
INVEST Operations and Maintenance Module Scoring Key

Results of the scoring workshops for each of the 14 OM criteria are presented below, organized as follows:

Each **criterion** is introduced by identifier and title, followed by the overall score for that criterion (in light blue), and a brief description extracted from INVEST guidance materials. A summary scoring chart shows possible points for each sub-criterion (indicated by identifier only), with bars in solid blue representing points achieved and bars in patterned blue representing points not achieved (see following for formatting).

OM-0x: Title Here

x/15 points



Each **sub-criterion** is then presented, starting with the identifier, the title, and, on the following line, points achieved (in light blue). For sub-criteria that are further divided, each element is bulleted, with identifier, title, and points achieved included on the same line. A brief, summary level scoring explanation is also included:

Requirement OM-01.3: Components of a Comprehensive Internal Sustainability Plan

x/3 points

- Requirement OM-01.3a: Coordination (x/1 point)

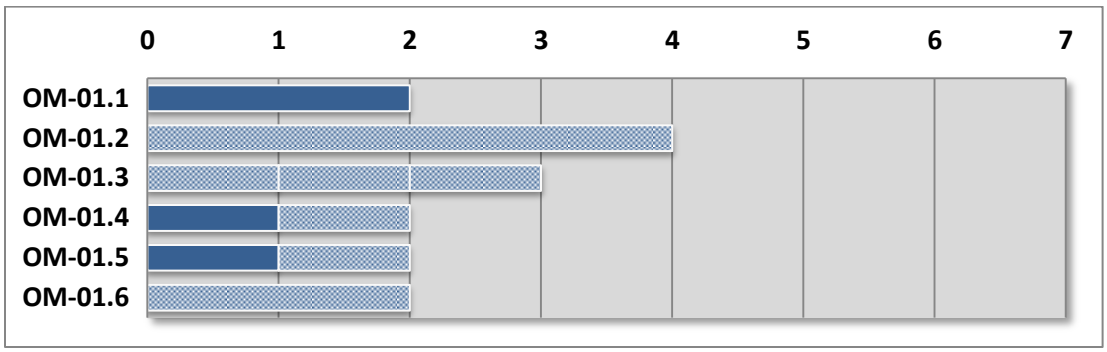
  Explanatory Notes - The agency meets this requirement because . . .

ADOT INVEST Operations and Maintenance Module Scoring Results

OM-01: Internal Sustainability Plan

4/15 points

Focus on sustainability improvements within the agency's internal operations that affect all three principles of the triple bottom line.



-Requirement OM-01.1: Executive Commitment

2/2 points

While ADOT senior leadership has not enacted an overarching, agency-wide sustainability policy, several initiatives demonstrate commitment. These initiatives include applying the INVEST Project Development and Operations & Maintenance modules, the ITD sustainability program annual report, and the MPD sustainability plan's commitments for external projects, among others.

-Requirement OM-01.2: Develop a Comprehensive Internal Sustainability Plan

0/4 points

ADOT has not yet developed a Comprehensive Internal Sustainability Plan (CISP). Although ADOT has some sustainability initiatives in place, it has yet to consolidate these into one formal plan. The agency has established some sustainability goals, strategies and actions, but it has yet to adopt sustainability-specific performance measures and targets. The INVEST module pilots are considered groundwork for a future CISP.

-Requirement OM-01.3: Components of a Comprehensive Internal Sustainability Plan

0/3 points

- *Requirement OM-01.3a: Coordination (0/1 point)*

  The agency does not have a CISP and thus does not meet this requirement.

- *Requirement OM-01.3b: Implementation (0/1 point)*

  The agency does not have a CISP and thus does not meet this requirement.

- *Requirement OM-01.3c: Monitoring and Tracking (0/1 point)*

  The agency does not have a CISP and thus does not meet this requirement.

-Requirement OM-01.4: Employee Engagement and Training
1/2 points

- *Requirement OM-01.4a: Sustainability Training (0/1 point)*

  The agency does not have a CISP and thus does not meet this requirement.

- *Requirement OM-01.4b: Employee Sustainability Committee (1/1 point)*

ADOT does have several individuals and teams working to champion sustainability at the agency. While this effort could be more coordinated, it has resulted in several important initiatives, including an Extreme Weather Vulnerability Assessment (an FHWA Climate Resilience Pilot), INVEST workshops, the establishment of an agency sustainability award, and the ADOT Green Shops program[1].

-Requirement OM-01.5: Commuting Options
1/2 points

- *Requirement OM-01.5a: Implement Travel Demand Management Options (1/1 point)*

  ADOT implements several travel demand management options for employees, including compressed work weeks, alternative working hours, carpooling/vanpooling support, virtual meetings, teleworking options, bicycle and pedestrian amenities, and subsidized transit.

- *Requirement OM-01.5b: Provide Support for Alternative Fuel Vehicles (0/1 point)*

  ADOT does not provide support for alternative fuel vehicles used for commuting at this time.

-Requirement OM-01.6: Demonstrate Sustainable Outcomes
0/2 points

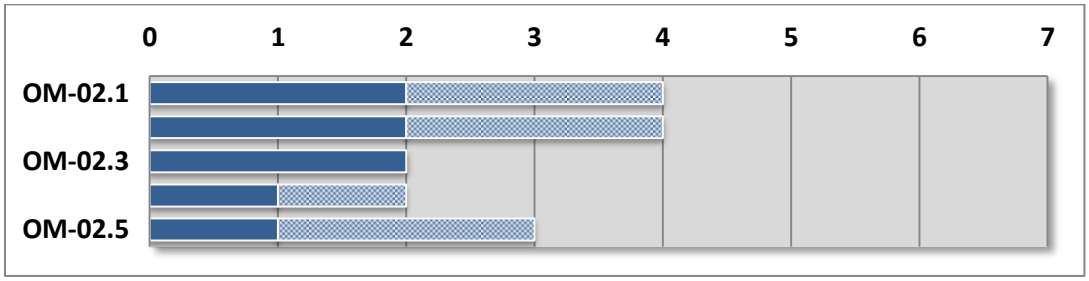
The agency does not have a CISP and thus does not meet this requirement.

[1] The Green Shop program was developed in 2006. As part of the program, a specialized environmental team within the Equipment Services work group developed the Equipment Services Best Management Practices Manual to give shops a guide on reducing pollution and improving operations within the shops in an environmentally sensitive manner. See also Appendix G.

OM-02: Electrical Energy Efficiency and Use

8/15 points

Reduce the consumption of fossil fuels during operation and maintenance of agency owned and/or operated facilities through improvements in efficiency and the use and/or generation of renewable energy sources.



-Requirement OM-02.1: Set Energy Reduction and Renewable Energy Usage Goals

2/4 points

- *Requirement OM-02.1a: Set Energy Reduction Goal (2/2 points)*

  The Arizona legislature mandates a 15% energy reduction from a 2002 baseline. The agency is currently at a 24% reduction.

- *Requirement OM-02.1b: Set Goal for Buying Renewable Energy Credits (RECs) (0/2 points)*

  ADOT does not have a goal for buying RECs or a renewable portfolio standard. The state legislature has not voted for REC goals or mandates.

-Requirement OM-02.2: Develop a Plan

2/4 points

ADOT has informal plans and chain-of-command directives to meet its energy reduction goal, but does not have renewable energy usage goals and thus is ineligible for all four points. While the agency lacks a single consolidated document, ADOT's energy reduction planning is apparent:

- An ADOT facilities manager oversees the agency's energy bills, manages its budget, and maintains a list of energy efficiency-related projects.

- Energy reduction is a consideration in all relevant ADOT facilities projects (i.e., affecting buildings and other non-roadway facilities owned or operated by ADOT).

- ADOT has written documentation of its energy reduction measures with utilities, including Arizona Public Service Company (APS) and UniSource Energy Services. APS, for instance, pays ADOT to replace older ballasts and lamps after certain intervals to conserve electricity. ADOT has developed a light fixture replacement schedule accordingly. Since 2006, ADOT has saved over 7 million KWh, or nearly $900,000, through APS's Solutions for Business program.

- Energy savings projects are also included in ADOT's 2-year building renewal plans submitted to the state legislature.

-Requirement OM-02.3: Measure Progress and Monitor Performance
2/2 points

ADOT keeps a detailed spreadsheet of its electricity utility bills at 89 different facilities, reviews every bill to uncover anomalies or inefficiencies, and tracks progress over time.

-Requirement OM-02.4: Employee Awareness Program
1/2 points

- *Requirement OM-02.4a: Employee Awareness Program (1/1 point)*

  ADOT's internal newspaper has published several articles emphasizing electricity reduction. The facilities team has automated several energy savings measures, such as occupancy sensors for lighting and thermostats with lock-out features.

- *Requirement OM-02.4b: Employee Energy Reduction Committee (0/1 point)*

  ADOT does not have an Employee Energy Reduction Committee at this time.

-Requirement OM-02.5: Demonstrate Sustainable Outcomes
1/3 points

- *Requirement OM-02.5a: Execute Renewable Energy Contract (0/2 points)*

  The agency does not have a renewable energy goal.

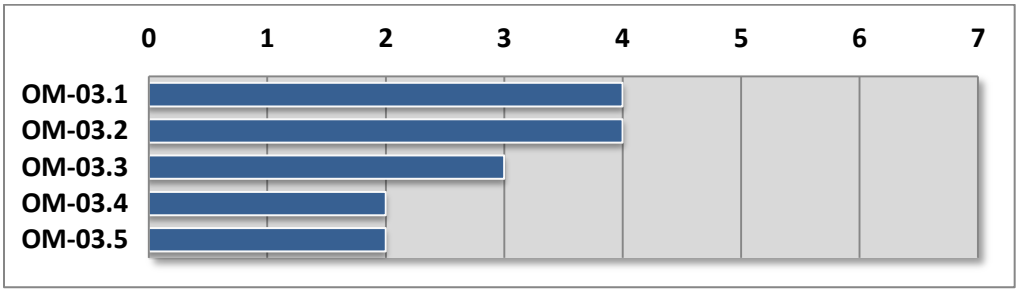
- *Requirement OM-02.5b: Monitor Performance and Demonstrate Sustainable Outcomes (1/1 point)*

  The agency has closely tracked energy consumption and demonstrated an energy reduction of 24% from the 2002 baseline.

OM-03: Vehicle Fuel Efficiency and Use

15/15 points

Reduce fossil fuel use and emissions in vehicles used for operations and maintenance.



-Requirement OM-03.1: Set Fuel Usage Goals

4/4 points

ADOT sets goals for maximizing fuel economy rather than instituting consumption goals. Goals are set for both light- and heavy-duty fleets. As fuel efficiency technologies continue to evolve and ADOT replaces older vehicles, its fleet has become more efficient. ADOT tends to look at fuel consumption on a project level rather than agency level; fuel usage varies based on the number and character of projects and programs at any given time.

At the district level, ADOT deploys an Automated Motor Vehicle Pool (AMP), which helps maximize utilization of its existing fleet. By automating fleet management processes, such as reservation of vehicles by different agency staff, AMP enables ADOT to fulfill its mission with a smaller fleet, indirectly promoting fuel efficiency. The agency also closely monitors fuel consumption and reserves. By using Personal Identification Numbers (PINs) for refueling, the agency can accurately track usage by employee.

-Requirement OM-03.2: Develop a Fleet Management Plan

4/4 points

ADOT has many of the essential elements of a fleet management plan, though the plan is not consolidated. A key piece of ADOT's fleet management is a spreadsheet tool that ranks vehicles by replacement needs based on established criteria, including fuel economy. This systematic management approach helps ensure that the agency replaces vehicles by need rather than want and steers fleet budgeting. Fleet management elements include:

- Alternate energy sources: OM-03.3 discusses the agency's alternative fuel analysis and considerations.
- Anti-idling: ADOT's leadership has pushed to minimize idling. The agency has installed Automatic Vehicle Location (AVL) technology that automatically shuts off vehicles after a certain idling duration and sends idling reports to fleet management. Some vehicles have solar light bars for lighting while vehicles are not running that were part of a 2010 effort.
- Maintenance and operation: The agency has a formal vehicle maintenance plan and equipment services BMP (best management practices) manual.

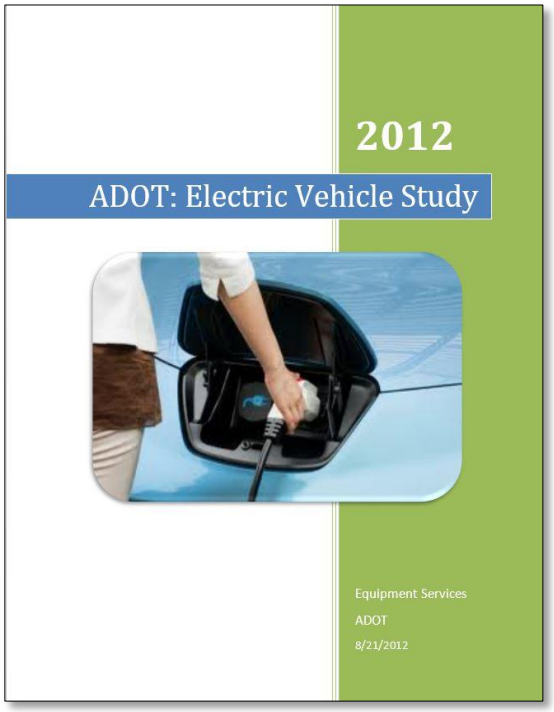
- Right-sizing vehicles: The agency closely monitors the size of each vehicle purchased, requiring justification for larger vehicle purchase requests.

- Vehicle technologies: Telematics allows the agency to closely manage VMT for each vehicle. ADOT snow plows use wing plows and GPS to maximize efficiency and minimize fuel usage.

- Employee training: The agency has vehicle training departments for technicians and equipment operators. ADOT's Zonar fleet management software reinforces this training by tracking pre- and post-trip tests (e.g., brake tests) and helps monitor driver speed and idle times.

-Requirement OM-03.3: Test Alternative Fuels and Reduction Methods
3/3 points

The agency conducted an extensive alternative fuel vehicle study in 2012 and found that alternative fuel vehicles are not operationally or fiscally viable options at this time. For example, at the time of the study, one of the agency's standard fuel light-duty vehicles, the Chevrolet Impala, cost $17,000 versus a comparable electric vehicle that cost $45,000. The viability of electric vehicles is also limited by Arizona's relatively large land area; compared to conventional vehicles, electric vehicles have relatively shorter ranges and slower refueling (charging) times. Air conditioning, a relatively frequent need given Arizona's generally hot climate, also reduces the range of electric vehicles significantly. Hybrids are better options for ADOT; the study found the Toyota Prius to be a suitable option but is currently unable to purchase these vehicles due to vendor contracting restrictions. ADOT also has a Liquefied Natural Gas (LNG) fueling station; it previously had two but took one offline due to limited use. The agency plans to regularly revisit alternative fuel options.



-Requirement OM-03.4: Measure Progress and Monitor Performance
2/2 points

The spreadsheet tool discussed in OM-03.3 helps the agency measure progress and monitor fleet performance. Regular fuel monitoring reports show target versus actual miles per gallon, which helps identify potential idling. The agency's fuel department observes these reports closely for anomalies in consumption.

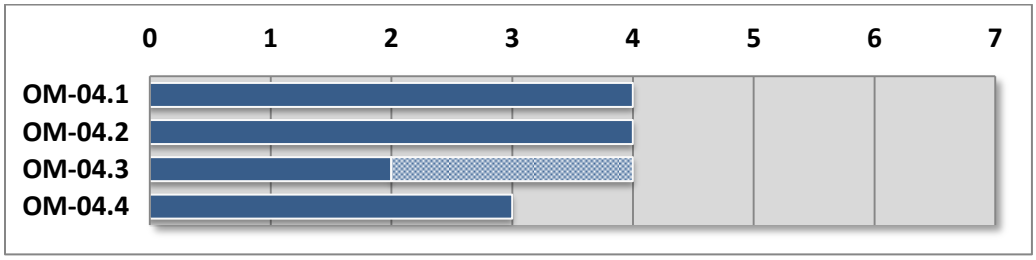
-Requirement OM-03.5: Demonstrate Sustainable Outcomes
2/2 points

The agency has used its fleet management spreadsheet and shown a progression of improved fuel economy for several years.

OM-04: Reuse and Recycle

13/15 points

Create and pursue a formal recycling and reuse plan for agency operated facilities and maintenance activities.



-Requirement OM-04.1: Set Recycle and Reuse Goals

4/4 points

The agency's internationally recognized Green Shop Program scores equipment services shops on a point system for eliminating, reusing, and recycling waste. The coveted Green Shop awards are given to shops that go above and beyond standard waste management practices. In addition to maintenance and operations, ADOT's internal facilities have recycling protocols.

ADOT has established BMPs to make sure different types of waste are addressed properly and has assigned staff to manage these processes.

-Requirement OM-04.2: Develop a Recycle and Reuse Plan

4/4 points

ADOT has standard operating procedures for both administrative and OM waste. The Green Shop program has 325 detailed inspection points for waste management. For example, shops lose a point if lids are not on its waste receptacles. Internally, the agency mandates recycling for certain materials, clearly labels waste receptacles, and notifies staff of recycling expectations. The Surplus Property Management Office's State Surplus Property Reference Manual serves as the overarching plan for the state's waste. The Surplus Office exists separately from ADOT as part of the Arizona Department of Administration, General Services Division.

-Requirement OM-04.3: Measure Progress and Monitor Performance

2/4 points

The Green Shop program tracks waste streams from maintenance and operations processes. The agency does not track its internal facilities waste streams directly and is therefore ineligible for all four points, but the State Surplus Office, which exists separately from ADOT, does quantify waste by type.

-Requirement OM-04.4: Demonstrate Sustainable Outcomes

3/3 points

The Green Shop program has been measuring performance since 2006 and is recognized nationally and internationally for its progress.

REPORT HIGHLIGHT – ADOT Equipment Services Green Shops Program

Recognizing the environmental impact of the automotive repair industry, ADOT Equipment Services Division's **Environmental Green Shop Award Program** provides employee education and recognition regarding environmental practices throughout the twenty-two (22) vehicle service and repair shops statewide.

The Environmental Green Shop Award Program is a detailed initiative which began in 2008 to implement education programs to help promote 'green' operational practices, reduce waste, and improve sustainability. Through this program, our equipment repair shops, their employees, and the environment all benefit. Using education as a significant tool to prevent pollution and protect the environment, the effort increases participation and adoption of sustainable practices to promote environmental stewardship to even higher standards. Continuous improvement in the workplace, where all employees are trained in environmental work practices and procedures, aid in meeting those goals and taking personal responsibility for protecting the environment. The success of our education program fosters employee engagement in environmental sustainability and embeds such values into the organizational culture allowing employees to be a 'sustainability champion' which can unleash their potential to make a difference.

The ADOT Environmental Green Shop Award Program promotes employee participation as an environmental activity and rewards the "Top Shop" for their commitment to being great stewards. Winning shops receive a Green Shop Flag, a Green Shop Banner to hang inside their shop, an award plaque, and individual Star Performer Awards. The ceremony also includes the ADOT Director presenting the awards to the shop team members.

The impact of employee training, educational projects, and the green initiatives that Green Shops has put into practice has significantly reduced and eliminated the amount of waste generated. This can best be explained through the process of recycling thousands of used tires, lead-acid batteries, and filters along with tons of scrap metal, paper, cardboard, plastics, aluminum cans, and thousands of gallons of motor oils as well as other fluids. In addition, Green Shops has realized savings on chemical purchases, disposal costs, regulatory monitoring, reporting and permitting fees, and water, electricity and sewer use charges.

The Program evaluates the impact of its operations on the environment with measureable results and provides an opportunity to apply environmental best management practices (BMPs) to shop operations, and thus reduce the cost, carbon footprint, and energy consumption of our workplace infrastructure state-wide. Through education and training employees are encouraged to reuse, recycle, conserve energy, water, consumables, and petroleum fuel use, participate in activities in pollution prevention, minimize waste generation and emissions, identify source reduction, solid wastes to landfills, and increase sustainability. The Program empowers employees to go 'above and beyond' to make a meaningful difference.

One of the environmental education tools used in the program is the Best Management Practice Manual or BMP Manual which educates employees about environmental issues. BMPs are proven guidelines and methods that reduce pollution and improve and enhance operational capabilities in an environmentally sensitive manner. Most of the efforts to make our shops 'green' have come from implementing BMPs. Shops are now implementing more than 300 'above and beyond' environmentally conscious BMPs changing from pollution-generating behaviors to pollution-prevention behaviors.

Another environmental education tool is the Self-Audit Environmental Compliance Checklist or Green Shop Checklist, which aids in implementing environmental education lessons. The Checklist is used to ensure shops follow the BMPs bridging the gap between the goal and the reality of environmental accountability. Each shop completes a self-audit inspection using the Checklist to identify and select best practice and to help identify some of the things that might be done better. Personal interviews, training, and announced and unannounced audits are used to measure progress and yield extensive data collection, review, validation, documentation, communication, and reporting results to assist with any emerging issues. A scoring metric for the overall implementation of BMPs was developed and the Green Shop Award recipients are chosen based on this numerical rating system. The shop with the highest score is the winner.

The Green Shop Checklist is divided into five parts. Part I. Environmental Compliance, ensures proper management practices that help minimize wastes, reduce downtime, and keep shop in compliance with regulations. Part II. Quest For A Green Shop, identifies environmentally friendly practices that reduce pollution and impact environmental sustainability. Less waste means lower disposal and operating costs and efficient use of materials, water, and energy saves money. Part III. Workplace Housekeeping, ensures a safer and healthier workplace for employees and customers. Part IV. Action Plan, creates a site-specific action plan to continue to move each shop towards a more 'green' workplace. Part V. Personal Effects of Going Green highlights superior 'above and beyond' environmental practices that affect the shop's image with customers, and regulatory agencies which are shared with all Equipment Services shops and together augment the Environmental Green Shop Award Programs' impact.

The Green Shop Checklist and BMP Manual highlight important environmental requirements for automotive repair shops and provides a series of educational training topics. If problems with compliance are discovered while completing the Checklist, educational outreach and technical assistance is provided.

The Environmental Green Shop Award Program has been a good first step toward getting employees involved in an educational process to build a culture of sustainability. Equipment shops look to the Program to lead the transition from a disposal-based business to one that conserves resources for future use as a first choice and a way to save money and improve individual shop sustainability as well as agency sustainability.

The Environmental Green Shop Award Program continues to enhance employees' knowledge, understanding, and confidence level with hands on activities applying new evaluation knowledge and skills

with emphasis on implementing real environmental solutions that deliver a cleaner environment and encourages a long-lasting, sustainable commitment to protecting public health and improving and preserving Arizona's beautiful natural surroundings.

REPORT HIGHLIGHT – Equipment Services Operations

One example of waste reduction was the creation of spray guards for ADOT's boot trucks. The boot trucks spray emulsion onto pavement; previously, the spray heavily coated the truck, and sometimes the surrounding air, vehicles, and vegetation. The agency created rubber guards to contain the spray, minimizing environmental and equipment damage. ADOT made custom wash basins with spray washers to clean the guards and route byproduct into bins for proper disposal.

Batteries stored indoors away from storm and sanitary sewer drains, right side up, not stacked, with non-metallic watertight secondary containment.

Good housekeeping measures keeps shops clean and orderly.

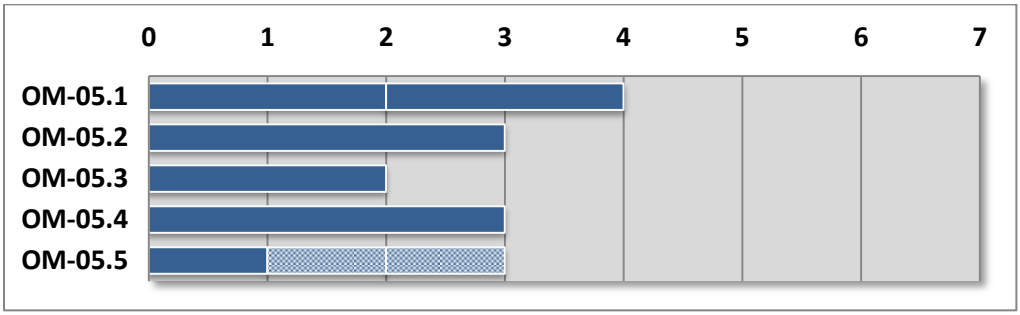
Oil storage drums with pumps to overhead reels system with secondary containment for drums.

Water-based (aqueous) based parts cleaning system in place of spray solvents.

OM-05: Safety Management

13/15 points

Maximize the safety of the existing roadway network through a systematic and comprehensive review of safety data and the allocation of resources in planning and programming to support safety in operations and maintenance.



-Requirement OM-05.1: Assess Current Safety Performance

4/4 points

- *Requirement OM-05.1a: Evaluate Safety Performance (2/2 points)*

The Strategic Highway Safety Plan (SHSP) evaluates safety performance across twelve different crash types. These crash types include behavioral categories, such as unbelted crashes.

- *Requirement OM-05.1b: Identify Safety Performance Metrics (2/2 points)*

  The SHSP has performance metrics for each crash type, including behavior-related metrics that reflect the portion of overall crashes where these behaviors are present.

-Requirement OM-05.2: Set Goals and Targets

3/3 points

- *Requirement OM-05.2a: Set Safety Goals (2/2 points)*

ADOT's SHSP sets long-term and intermediate safety goals. Individual teams set targets for each category. Several targets would require external laws, regulations, and policies, such as the state legislature passing a primary seatbelt law or motorcycle helmet law.

- *Requirement OM-05.2b: Integrate Safety Goals with Maintenance and Operations (1/1 point)*

Safety goals are effectively integrated into these activities. The safety team remarks that safety goals are an element of but not the be-all and end-all, ADOT's new planning-to-programming (P2P) initiative.

-Requirement OM-05.3: Develop a Plan
2/2 points

- *Requirement OM-05.3a: Develop a Statewide Safety Plan (1/1 point)*

  The SHSP fulfills this requirement.

- *Requirement OM-05.3b: Include Strategies and Activities to Support Improvement of Data and Analysis (1/1 point)*

  The SHSP stresses the importance of data management and analysis and has its own data improvement element. The agency is working to improve its data inventory and is in the process of integrating its safety data into GIS. ADOT uses a tool called Safety Analyst to integrate local data into one platform.

-Requirement OM-05.4: Implement the Plan
3/3 points

ADOT implements its SHSP in an integrated and multidisciplinary manner and addresses all of the criterion's required elements.

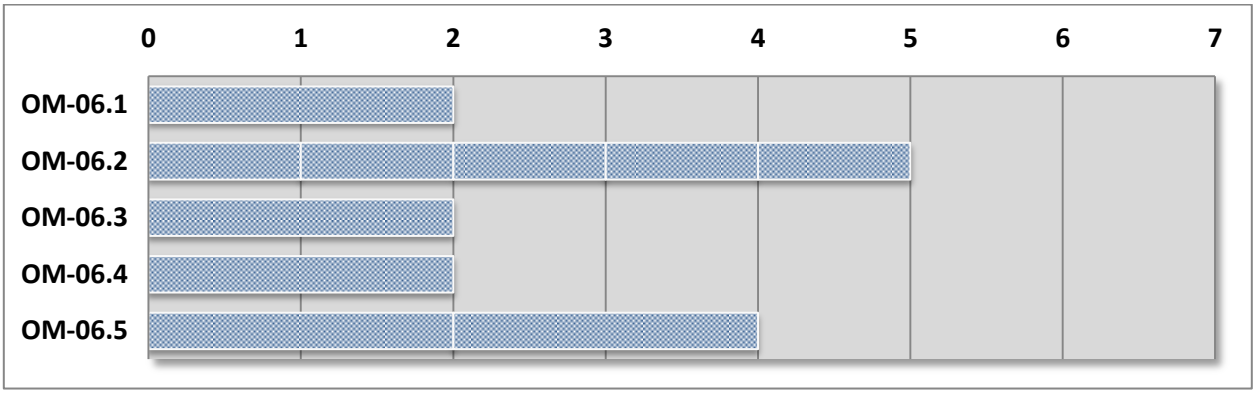
-Requirement OM-05.5: Measure Progress and Monitor Performance
1/3 points

ADOT uses Safety Analyst to measure progress and monitor performance, but not on a statewide basis. The department uses advanced and statistically sound performance evaluations on a project basis. The Safety Analyst tool should help ADOT to expand the scope of monitoring activities to cover the entire State system in the future.

OM-06: Environmental Commitments Tracking System

0/15 points

Ensure that environmental commitments made during project development related to operations and maintenance are documented, tracked, and fulfilled.



-Requirement OM-06.1: Develop a Comprehensive Environmental Compliance Tracking System (ECTS)

0/2 points

ADOT does not have a formal comprehensive Environmental Compliance Tracking System (ECTS). It uses multiple systems to comply with State and federal requirements each year.

Currently the project development team submits mitigation measures for each individual project. These measures are input into the construction database and included in contract documents. Finally, the agency's Intelex software produces a report on environmental performance, where monitoring and feedback are available. However, the current system does not have a systematic and comprehensive monitoring and feedback mechanism in place.

The agency is moving toward identifying all environmental commitments on a single list, as OM-06 alludes to, but this has not yet been fully established. Certain projects do trigger maintenance work orders that require District Environmental Coordinators to review[2]. While the agency's maintenance performance control system, PeCoS, tracks the agency's labor, it does not currently look upstream at project environmental requirements.

Overall, the agency recognizes the need to comprehensively define what it needs to track for environmental purposes and integrate this tracking into its existing processes.

-Requirement OM-06.2: Integrate Key Functions of an ECTS

0/5 points

- *Requirement OM-06.2a: Communicate from Planning through Operations and Maintenance (0/1 point)*

  ADOT does not have an ECTS.

[2] Some maintenance projects trigger more extensive environmental review if permitting may be involved.

- *Requirement OM-06.2b: Leverage Tracking Mechanisms (0/1 point)*

  ADOT does not have an ECTS.

- *Requirement OM-06.2c: Identify Training Needs (0/1 point)*

  ADOT does not have an ECTS.

- *Requirement OM-06.2d: Provide Reports (0/1 point)*

  ADOT does not have an ECTS.

- *Requirement OM-06.2e: Establish Quantifiable Performance Metrics (0/1 point)*

  ADOT does not have an ECTS.

-Requirement OM-06.3: Require Use of ECTS
0/2 points

ADOT does not have an ECTS.

-Requirement OM-06.4: GIS-based ECTS
0/2 points

ADOT does not have an ECTS.

-Requirement OM-06.5: Measure Progress and Monitor Performance
0/4 points

- *Requirement OM-06.5a: Set Goals (0/2 points)*

  ADOT does not have an ECTS.

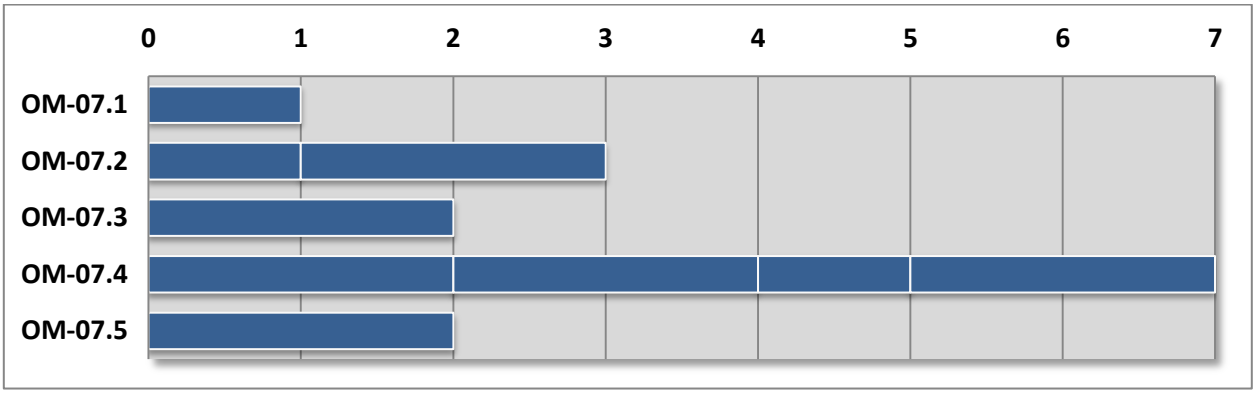
- *Requirement OM-06.5b: Measure Performance and Demonstrate Sustainable Outcomes (0/2 points)*

  ADOT does not have an ECTS.

OM-07: Pavement Management System

15/15 points

Leverage a pavement management system to balance activities that extend the life and function of pavements with impacts to the human and natural environment.



-Requirement OM-07.1: Develop a Pavement Management System and Collect Data

1/1 point

ADOT has a Pavement Management System (PMS). System elements include:

- An inventory of pavement assets;
- An annual assessment of pavement condition;
- Determination of pavement investment needs:
- Prioritization of pavement improvement projects;
- A forecast of the impact of investments on pavement condition; and
- A process for integrating results into the process (i.e., a feedback loop).

The PMS collects system-wide data.

-Requirement OM-07.2: Track Pavement Network Performance

3/3 points

- *Requirement OM-07.2a: Use Common Metrics (1/1 point)*

  ADOT tracks pavement using common metrics, including the International Roughness Index (IRI).

- *Requirement OM-07.2b: Measure Project Timelines (2/2 points)*

  The PMS identifies projects and activities to be completed within three years and includes detailed project histories.

-Requirement OM-07.3: Set Goals and Monitor Progress
2/2 points

ADOT sets quantifiable goals for pavement condition, such as a target percentage of roads in acceptable or better condition. It has monitored progress toward these goals for several years. The pavement team reports conditions to FHWA's Highway Performance Monitoring System (HPMS) and the ADOT Multimodal Planning Division's performance management system.

-Requirement OM-07.4: Leverage Data to Demonstrate Sustainable Outcomes
7/7 points

- *Requirement OM-07.4a: Leverage PMS Data to Prioritize Projects (2/2 points)*

  ADOT leverages PMS data and traffic counts to prioritize projects.

- *Requirement OM-07.4b: Leverage Life Cycle Cost Analysis (LCCA) to Predict Costs (2/2 points)*

  ADOT performs LCCA to predict short- and long-term costs every year.

- *Requirement OM-07.4c: Include Pavement Preservation in Annual Plan (1/1 point)*

  ADOT's STIP includes lump sum pavement preservation needs.

- *Requirement OM-07.4b: Link Pavement Repair, Preservation and Maintenance to Projects (2/2 points)*

  Pavement preservation and maintenance activities are linked to capital projects.

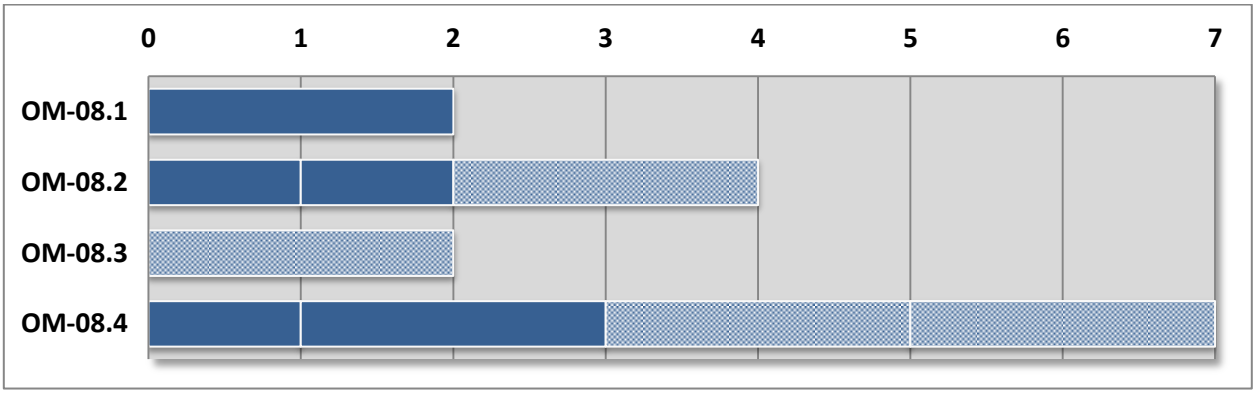
-Requirement OM-07.5: Sustainable Specifications
2/2 points

ADOT's pavement team always considers sustainable pavements for its projects. Sustainable pavements are used when they are the best option available. The team notes that some pavements made from recycled products require replacement after only 15 years (meaning that, from a lifecycle perspective, they may not provide the best value or be the most sustainable option for some applications).

OM-08: Bridge Management System

7/15 points

Leverage a bridge management system (BMS) to balance activities that extend the life and function of bridges with impacts to the human and natural environment.



-Requirement OM-08.1: Develop a Bridge Management System and Collect Data

2/2 points

ADOT's Bridge Management System (BMS) performs the following functions:

- Collects, processes, and updates data;
- Predicts deterioration;
- Identifies alternative actions (e.g., treatment programs);
- Predicts program costs;
- Helps determine optimal investment policies;
- Performs short- and long-term budget forecasting; and
- Recommends bridge preservation investments that conform to policy directives and budget constraints.

The BMS collects systemwide data.

-Requirement OM-08.2: Track Bridge Network Performance

2/4 points

- *Requirement OM-08.2a: Track Overall Bridge Network Condition Using Common Metrics (1/1 point)*

  The BMS tracks good/fair/poor bridge condition ratings and National Bridge Inventory (NBI) ratings. ADOT reports individual and system wide bridge performance.

- *Requirement OM-08.2b: Operational Limits (1/1 point)*

  ADOT reports operational limits as part of the NBI.

- *Requirement OM-08.2c: Project Timeliness (0/2 points)*

  The agency now has the ability to track project timeliness with its new BMS software, but has not yet done so.

-Requirement OM-08.3: Set Goals and Monitor Performance
0/2 points

ADOT's overarching goal is to limit structurally deficient bridges to 10% or less of the state's total bridges, but does not meet INVEST goals for monitoring yet.

-Requirement OM-08.4: Leverage Data to Demonstrate Sustainable Outcomes
3/7 points

- *Requirement OM-08.4a: Use BMS to Perform Sophisticated Modeling (0/2 points)*

  The bridge team plans to perform sophisticated modeling in the future and is in its first year of data collection for this task (at least two years of data required).

- *Requirement OM-08.4b: Leverage LCCA to Predict Costs (0/2 points)*

  ADOT does not yet leverage LCCA to predict project life cycle costs.

- *Requirement OM-08.4c: Include Preservation in Annual Plan (1/1 point)*

  ADOT's STIP includes bridge preservation needs.

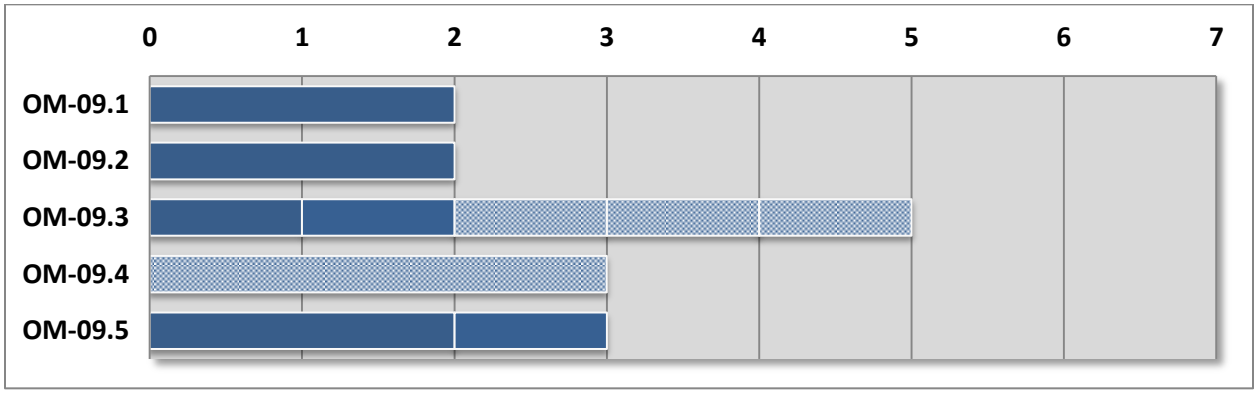
- *Requirement OM-08.4d: Link Repair, Preservation and Maintenance to Projects (2/2 points)*

  The agency uses direct staff communication (rather than software integration) to link bridge preservation activities to adjacent capital projects.

OM-09: Maintenance Management System

9/15 points

Leverage a Maintenance Management System (MMS) to inventory, assess, analyze, plan, program, implement, and monitor maintenance activities to effectively and efficiently extend the life of the system, improve the service, and reduce the impacts to the human and natural environment.



-Requirement OM-09.1: Integrate Key Elements of MMS

2/2 points

ADOT has five of the six key elements of an MMS. PeCoS serves as the maintenance performance maintenance control system. The agency employs the Feature Inventory System (FIS) for asset management and PeCoS and a predecessor system (LOS) for other planning functions including performance targets. The budget module exists outside of ADOT's maintenance management system but pulls data from PeCoS. PeCoS performs resource management tasks, work needs identification, and monitoring and evaluation, with robust reporting capabilities. Many of the maintenance support administration tasks, including risk and stockpile management, exist outside of PeCoS. ADOT's districts handle permit processing and tracking. ADOT does not have an automated short-term work scheduling module.

Figure 6. Maintenance Management Core Elements

-Requirement OM-09.2: Integrate Vehicle-Based Technology
2/2 points

ADOT leverages vehicle-based technologies to connect to its maintenance management systems. For example, ADOT's snow plows use GPS. The agency has equipped many of its vehicles with Automatic Vehicle Locators (AVL), and uses telematics to track mileage and fuel efficiency. Drivers and equipment operators provide end-of-shift reports that are entered into ADOT's systems. ADOT is currently equipping some of its drivers with tablets to gather more data and better manage its activities from the field.

-Requirement OM-09.3: Integrated Maintenance Management Systems
2/5 points

- *Requirement OM-09.3a: Roadway Inventory Systems (0/1 point)*

  This integration does not currently exist, but ADOT is in the process of establishing a connection between FIS and PeCoS.

- *Requirement OM-09.3b: Financial Management Systems (1/1 point)*

  ADOT's maintenance management system includes a financial module.

- *Requirement OM-09.3c: Construction/Project Management Systems (0/1 point)*

  This integration does not currently exist.

- *Requirement OM-09.3d: Equipment Management Systems (1/1 point)*

  ADOT's maintenance management system automatically pulls equipment management information.

- *Requirement OM-09.3e: Environmental Commitment Tracking System (0/1 point)*

  ADOT lacks a formal environmental commitment tracking system and its maintenance management system does not automatically access relevant environmental commitment information.

-Requirement OM-09.4: Leverage MMS to Define Projects
0/3 points

ADOT's maintenance management system is not fully integrated with its pavement and bridge management systems, though information is shared manually.

-Requirement OM-09.5: Maintenance Quality Assurance [MQA]
3/3 points

- *Requirement OM-09.5a: MQA Relates Maintenance to Performance (2/2 points)*

  ADOT's LOS (Level-of-Service) system relates highway maintenance activities to performance.

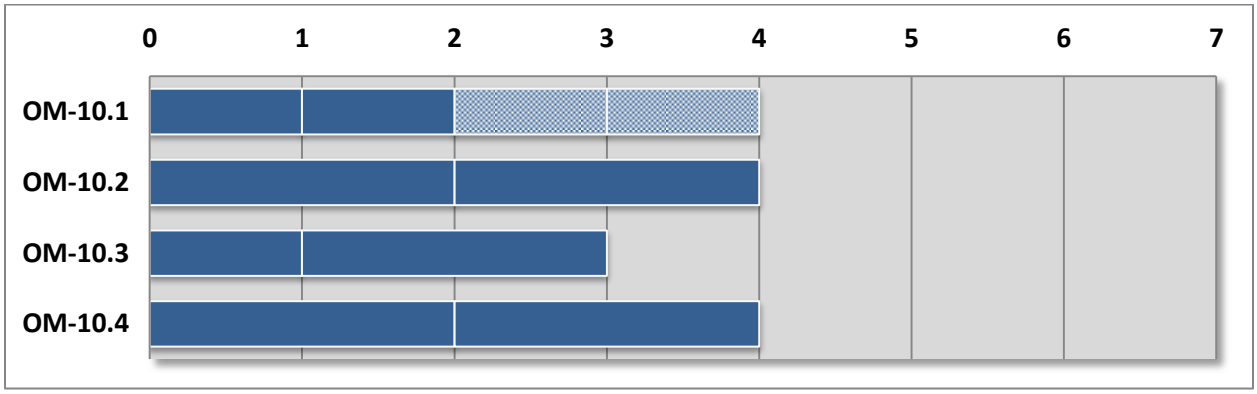
- *Requirement OM-09.5b: MQA Used to Understand Relationship between Costs and Outcomes (1/1 point)*

  The LOS system helps the agency develop strategies (such as preventative maintenance), set priorities, and document the relationship between costs and outcomes.

OM-10: Highway Infrastructure Preservation and Maintenance

13/15 points

Make paved roadway surfaces, bridges, tunnels, roadsides, and their appurtenance facilities last longer and perform better by undertaking preservation and routine maintenance on them.



-Requirement OM-10.1: Develop a Road Maintenance Plan

2/4 points

ADOT has a road maintenance plan consisting of multiple systems, Standard Operating Procedures (SOP), and documents that cover the core assets and several, but not all, of the additional assets. The plan is not consolidated. The systems, SOPs, and documents cover responsible parties, asset inventories, standards, schedules, funding sources, and preservation and maintenance.

ADOT has not yet integrated shoulders and sidewalks into its maintenance plans, though these facilities were added to the FIS. Currently these facilities are monitored during right-of-way inspections and on a complaint basis.

-Requirement OM-10.2: Establish Metrics and Measure Performance

4/4 points

- *Requirement OM-10.2a: Establish Quantifiable Metrics (2/2 points)*

  ADOT has established quantifiable metrics, though they exist in different places, including PeCoS and the LOS maintenance management program.

- *Requirement OM-10.2b: Use Metrics to Evaluate Performance (2/2 points)*

  ADOT uses its metrics to evaluate performance on at least an annual basis.

-Requirement OM-10.3: Set Goals and Monitor Progress

3/3 points

- *Requirement OM-10.3a: Set Quantifiable Goals (1/1 point)*

  ADOT sets quantifiable goals and letter grades for its assets.

- *Requirement OM-10.3b: Monitor Progress and Demonstrate Sustainable Outcomes (2/2 points)*

  The agency has monitored progress and showed measurable advancement toward goals for several years.

-Requirement OM-10.4: Sustainable Maintenance and Operations
4/4 points

- *Requirement OM-10.4a: RMP [Road Maintenance Plan] Highlights Activities that Contribute to Sustainability during Maintenance and Operations (2/2 points)*

  ADOT's Road Maintenance Plan highlights activities that contribute to sustainability during maintenance and operations. Some of these specifications are quantified in PeCoS guidelines and the agency's specifications and design guidelines. INVEST's example for this sub-criterion, non-idling SOPs, are in place at ADOT.

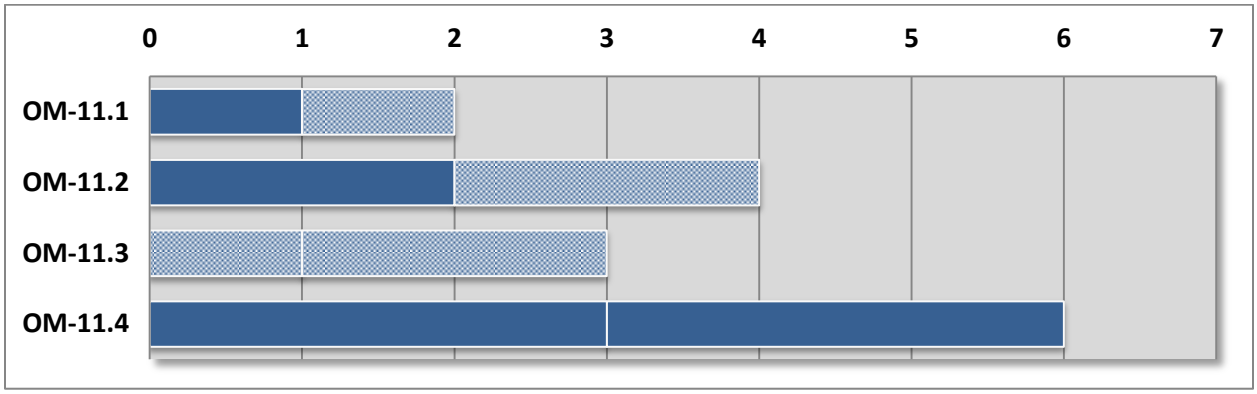
- *Requirement OM-10.4b: RMP Includes Activities that Contribute to Sustainability of Infrastructure Assets (2/2 points)*

  ADOT has finalized the *Complete Transportation Guidebook* to highlight sustainable approaches, products, and materials. Traditionally, when ADOT updates its design standards, it includes sustainable approaches, when relevant.

OM-11: Traffic Control Infrastructure Maintenance

9/15 points

Increase safety and operational efficiency by maintaining roadway traffic controls.



-Requirement OM-11.1: Develop a Traffic Control Maintenance Plan

1/2 points

ADOT has multiple Traffic Control Maintenance Plan (TCMP) components, including pavement marking/restriping; sign maintenance and retroreflectivity (tracked in FIS/LOS); safety devices (PeCoS); traffic signal maintenance (PeCoS); roadway lighting maintenance (PeCoS); and ITS maintenance. These systems are not integrated, and documentation is not consolidated.

-Requirement OM-11.2: Establish Metrics and Measure Performance

2/4 points

- *Requirement OM-11.2a: Establish Quantifiable Metrics (2/2 points)*

  The LOS maintenance program uses some quantifiable metrics related to signing and striping. Outside of LOS, another metric used is 'lights functioning as a percentage of total lights'.

- *Requirement OM-11.2b: Use Metrics to Evaluate Performance (0/2 points)*

  LOS measures are being used to help make funding decisions but not to evaluate overall performance or adequacy of traffic control maintenance.

-Requirement OM-11.3: Set Goals and Monitor Progress

0/3 points

- *Requirement OM-11.3a: Set Quantifiable Goals (0/1 point)*

  ADOT has not set quantifiable goals.

- *Requirement OM-11.3b: Monitor Progress Toward Goals (0/2 points)*

  ADOT has not set quantifiable goals and monitored progress for at least one year. This is the first year that LOS is being used to establish funding levels.

-Requirement OM-11.4: Sustainable Maintenance and Operations
6/6 points

- *Requirement OM-11.4a: TCMP Highlights Activities that Contribute to Sustainability during Maintenance and Operations (3/3 points)*

  ADOT's standard operating procedures mandate sustainable practices, including the limitation of vehicle idling. ADOT employs technologies like telematics to ensure that maintenance staff are adhering to SOPs.

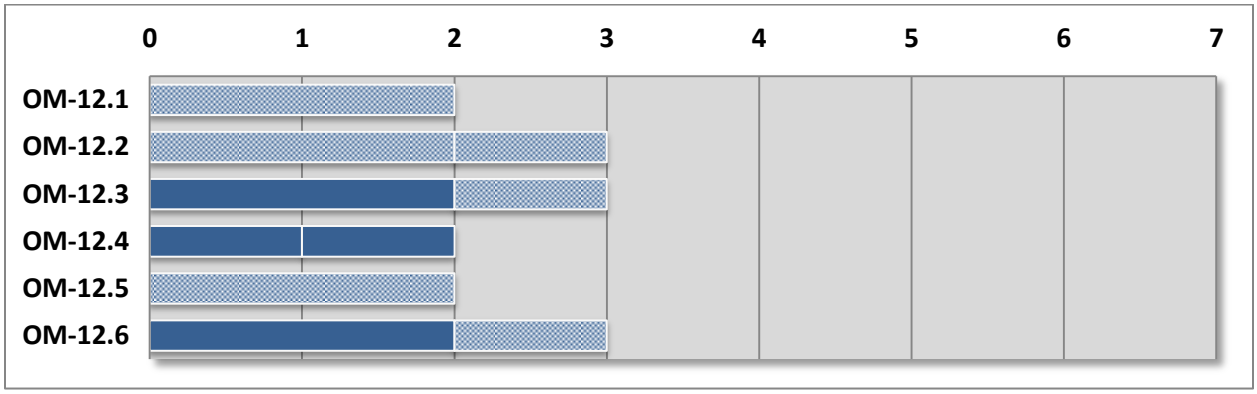
- *Requirement OM-11.4b: TCMP Includes Activities that Contribute to Sustainability of Infrastructure Assets (3/3 points)*

  ADOT's standard operating procedures, specifications, and guidelines contribute to the sustainability of infrastructure assets, including, but not limited to, the replacement of high-pressure sodium luminaires with LED fixtures, whenever feasible.

OM-12: Road Weather Management Program

6/15 points

Plan, implement, and monitor road weather management (including snow and ice control) program to reduce environmental impacts with continued or better level of service.



-Requirement OM-12.1: Develop a Road Weather Management Program

0/2 points

ADOT does not have a Road Weather Management Program (RWMP). While the agency has systems in place for managing some forms of inclement weather, particularly snow and ice, it has yet to establish a formal Road Weather Management Program.

-Requirement OM-12.2: Set Goals and Monitor Progress

0/3 points

- *Requirement OM-12.2a: Establish Quantifiable Metrics (0/2 points)*

  ADOT has not established formal performance metrics.

- *Requirement OM-12.2b: Monitor Progress and Demonstrate Sustainable Outcomes (0/1 point)*

  ADOT has not established formal performance metrics and thus has not monitored progress towards these goals.

-Requirement OM-12.3: Implement a Road Weather Information Systems

2/3 points

The agency implements a Roadway Weather Information System (RWIS) at 17 locations across the state. ADOT has several weather-related notifications on the web, including a winter weather blog.

-Requirement OM-12.4: Implement the Standards of Practice or Standard Operating Procedure (SOP) for Snow and Ice Control
2/2 points

- *Requirement OM-12.4a: RWMP that includes Snow and Ice Control Elements (1/1 point)*

  ADOT's RWMP covers salt reduction, anti-icing, training for proper use of salt and chemicals, BMPs for chemical storage facilities, proper storage of chemical stockpiles, proper calibration of equipment, and cost reduction/fuel efficiency measures.

- *Requirement OM-12.4b: Include Performance Standards to Demonstrate Sustainability (1/1 point)*

  The agency's program includes standards that account for sustainability and has demonstrated reduction in salt usage and increases in fuel efficiency. However, it is difficult to control for storm characteristics when using performance measures such as salt usage.

-Requirement OM-12.5: Implement Materials Management Plan
0/2 points

ADOT does not implement a materials management plan. The agency monitors Level of Service (LOS) but has not established LOS metrics for storms.

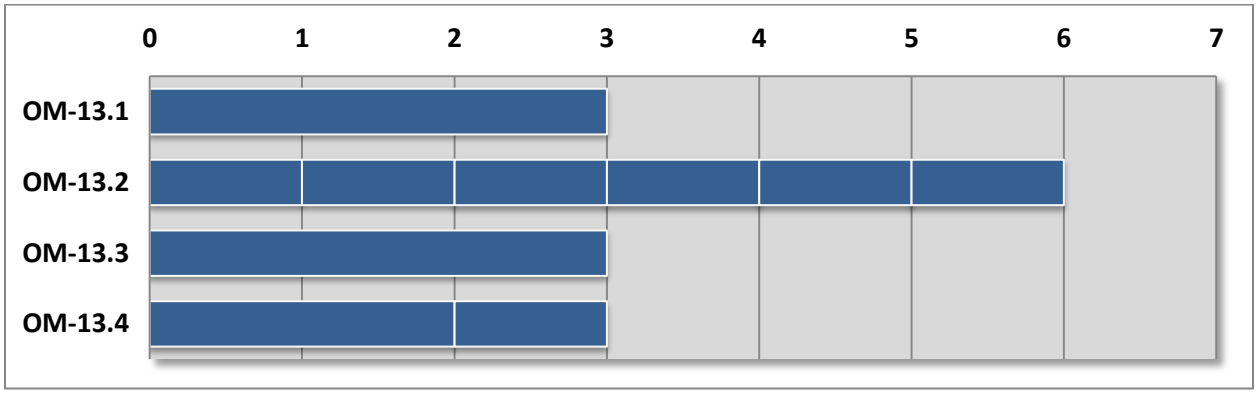
-Requirement OM-12.6: Implement a Maintenance Decision Support System
2/3 points

ADOT leverages sensing technologies to evaluate road weather.

OM-13: Transportation Management and Operations

15/15 points

Maximize the utility of the existing roadway network through use of technology and management of operations.



-Requirement OM-13.1: Conduct Enhanced or Expedited Compliance

3/3 points

ADOT has instituted enhanced transportation management and operations measures, particularly in the Phoenix metropolitan area.

-Requirement OM-13.2: Include Operation-Based Programs and Develop Performance Measures

6/6 points

Based on an interview with ADOT's traffic control group, the agency has implemented at least one ITS technology in at least seven different categories (defined by INVEST), as follows, earning ADOT all 6 available points (although other relevant ADOT activities, outside of the purview of traffic control, may not be reflected here).

OM 13.2a: Traffic Management	
☒	Statewide traffic operation
☒	Center coordinated traffic signal systems
☐	Local agency traffic management centers
☐	Traffic surveillance systems
☐	Traffic signal control systems
☐	Adaptive signal control systems
☐	Advanced signal systems
☐	Coordinated signal operations (inter-jurisdictional)
☐	Specialized signal heads

☐	Traffic control
☒	Lane management applications
☐	Special event transportation management systems
☐	Automated systems enforcing speed limits
☒	Traffic incident management
OM 13.2b: Traveler Information	
☒	Pre-trip information (Internet web sites, 511, other telephone, radio/ TV, or kiosks)
☒	En route information
☒	Traveler Services Information
OM 13.2c: Transit Management	
☐	Transit ITS and central operations
☐	Transit trip planner
☐	Transit signal priority
☐	Automatic vehicle location
☐	Computer-aided dispatch systems
☐	Operations and fleet management
☐	Advanced traveler information systems
☒	Integrated corridor management
OM 13.2d: Electronic Payment and Pricing	
☐	Electronic toll collection systems
☐	Multi-use payment systems
☐	Congestion pricing
OM 13.2e: Information Management	
☒	Archived data management systems
☒	Transportation management centers
☒	Information dissemination (portable dynamic message signs)
☒	Highway advisory radio
OM 13.2f: Road Weather Management	

☒	Road weather surveillance, monitoring, and prediction
☒	Advisory strategies (e.g., road weather information dissemination)
☐	Control strategies (e.g., traffic control based on adverse weather)
☒	Treatment strategies (e.g., winter maintenance)
OM 13.2g: Incident Management	
☐	Signal timing changes
☒	Detours and alternate routes
☒	511 messaging
☒	Information dissemination (portable dynamic message signs)
OM 13.2h: Communication linkages	
☐	Center-to center Communications
OM 13.2i: Commercial Vehicle Operations	
☐	Commercial vehicle information systems and networks • Credentials administration • Safety assurance • Electronic screening • Carrier operations and fleet management • Security operations • Weigh-in-motion stations
OM 13.2j: Emergency Management	
☐	Emergency medical services
☐	Hazardous materials management
☐	Advanced automated collision notification
☐	Telemedicine Response and recovery
☐	Emergency traveler information
☐	Early warning system
☐	Coordinated emergency response
☐	Collision notification systems

OM 13.2k: Advanced Vehicle Safety Systems	
☐	Road geometry warning
☐	Intersection collision warning systems
☐	Animal Warning
☐	Collision Avoidance systems
☐	Forward collision warning systems
☐	Road departure warning
☐	Lane departure warning
☒	Work zone management
☒	Winter maintenance

-Requirement OM-13.3: Integrate Operations Strategies and Projects into Systems Planning and Establish Performance Goals and Monitor Progress
3/3 points

ADOT integrates operations strategies and projects into systems planning and selectively establishes performance goals and monitors progress.

-Requirement OM-13.4: Set Goals and Monitor Progress
3/3 points

- *Requirement OM-13.4a: Establish Safety and Mobility Performance Metrics (2/2 points)*

  ADOT has at least one safety and one mobility performance metric relevant to the implementation of ITS solutions.

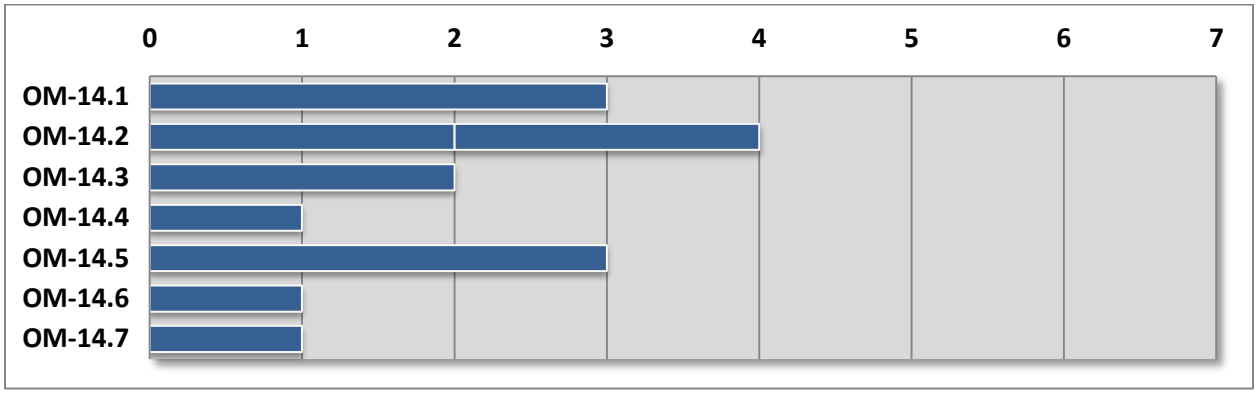
- *Requirement OM-13.4b: Monitor Progress and Demonstrate Sustainable Outcomes (1/1 point)*

  ADOT monitors progress towards transportation management and operations goals for at least one year and shows advancement.

OM-14: Work Zone Traffic Control

15/15 points

Plan, implement, and monitor Work Zone Traffic Control (WZTC) methods that maximize safety of workers and system users with continued or better level of service.



-Requirement OM-14.1: Develop a Program

3/3 points

ADOT has implemented a Work Zone Traffic Control (WZTC) program that incorporates all required elements, including: use FHWA's Work Zone Process Review Toolbox to conduct reviews; examine current work zone trends and issues in work zone safety (ADOT examines contributing factors to work zone crashes resulting in injury or fatality on a crash-by-crash basis); update/adopt new policies to correct shortcomings, as needed; work with law enforcement to ensure accurate reporting; provide training both for workers and in drivers' education courses; review new technologies; consider FHWA's WZTC self-assessment tool.

-Requirement OM-14.2: Set Goals and Monitor Progress

4/4 points

- *Requirement OM-14.2a: Establish Performance Metrics (2/2 points)*

  ADOT's established metric for work zone crashes is "zero tolerance"—*any* injury or fatality is considered to be too many.

- *Requirement OM-14.2b: Monitor Progress towards Goals (2/2 points)*

  ADOT has monitored progress toward the zero tolerance goal for the last 7-8 years.

-Requirement OM-14.3: Use ITS to Anticipate and Reduce Congestion

2/2 points

ADOT routinely uses ITS — in particular variable message boards/signs — to warn drivers of upcoming work and to reduce congestion.

-Requirement OM-14.4: Apply and Review ITS Technologies and Innovations
1/1 point

ADOT regularly reviews ITS technologies and innovations for work zones and applies new technologies as warranted. ADOT discourages the use of safety intrusion alarms because review has shown that they are not crash worthy.

-Requirement OM-14.5: Leverage Contracting Innovations
3/3 points

ADOT routinely uses innovative contracting to reduce and optimize construction time lines in both design-bid-build and design-build contracts.

-Requirement OM-14.6: Coordinate with the Public
1/1 point

ADOT conducts public outreach to property owners affected by construction activities and updates them regularly through direct communication and technology (e.g., Twitter).

-Requirement OM-14.7: Promote Public Awareness
1/1 point

ADOT has developed a campaign to promote work zone safety awareness.

Recent ADOT OM Sustainability Linkages

Arizona Holds Regional Traffic Incident Management Summit

Multidisciplinary leaders engaged in traffic incident management talks about ways to strengthen collaboration in the Southwest at a summit on December 9 and 10, 2015 in Phoenix, Arizona. Discussions included linking traffic incident management with safety, training, policies, procedures, performance measures, local challenges and the future of traffic incident management. The Arizona Department of Transportation, Arizona Department of Public Safety and Maricopa County Department of Transportation hosted the summit in partnership with the Arizona Council for Transportation Innovation, National Operations Center of Excellence and FHWA.

ADOT Northcentral District Initiates Best Management Practices – Winter Storm Management

It has been requested by management that ADOT Districts review contractor work during the winter months per guidance, with a specific focus on the efficiency of no temporary traffic control devices being permitted to be set up during the winter shutdown, specific to locations that have high snowfall accumulations. For some time, districts have practiced to 'not' allow temporary devices to stay in place during the winter months at high snow locations. The temporary traffic control devices interfere with winter snowplows and the plowing activities creating unnecessary damage to snowplows. When plows get damaged they can be lost for the remainder of the storm event, and at times even longer, hindering snow removal operations. In addition, the temporary traffic devices are extremely difficult to maintain during high snowfall storms events. More specific to temporary concrete barriers (TCBs); TCB produces a tunnel effect where snow drifts and accumulates quickly between the barriers and is difficult to keep clear during the winter storms.

Moving Forward with TSM&O

ADOT began moving forward with the implementation of a Transportation Systems Management and Operation (TSM&O) Division in October 2015. As with any major re-structuring of this kind there is a transition period. This TSM&O Division structure includes a centralized administrative model that will promote transparency and provide opportunities for career advancement. The oversight and management of the Maintenance Appropriation will reside in the office of the Deputy Director for Transportation. Administrative support remains in the current group/district until TSM&O is fully on line in later 2016. A group and/or person moving over to TSM&O will continue supporting some of the current Infrastructure Delivery and Operations functions (example - snow plowing).

High Friction Surface Treatments

FHWA Every Day Count primer states, "annually, over 25 percent of all highway fatalities in the United States occur at or near horizontal curves. Vehicle stopping and turning are critical safety functions, which begin with the tires contacting the pavement." HFSTs are pavement surfacing systems with exceptional skid-resistant properties not typically provided by conventional materials. The spot application of a thin layer of durable, high friction aggregates as a topping on specially engineered resin or a polymer binder affords long-lasting traction, while making the overlay much more resistant to wear and polishing. ADOT Traffic Engineering Guidelines and Processes identifies locations for consideration of HFST are identified by the Traffic Safety Section. District Engineers or Regional Traffic Engineers may recommend locations for evaluation by TSS. Implementation of HFST should be coordinated with the Pavement Preservation program and other projects within the 5-year Statewide Transportation Improvement Program.

Statewide Wireless/Solar Weigh-In-Motion System

The Statewide WIM System, is a proposed project that will add approximately 38 weigh-in-motion (WIM) sites throughout the State of Arizona and includes potential sites in each of ADOT's seven districts. Arizona currently has six Ports of Entry that provide weight enforcement for 7.5 million trucks annually. The Statewide Weigh-in-Motion system is a high-priority project for ADOT that is intended to support commercial vehicle operations throughout the state.

ADOT contracted to prepare a Feasibility Report and an environmental clearance document addressing the need for programming new Weigh-In-Motion (WIM) systems statewide. The ADOT project, managed by the ADOT Transportation Technology Group, serves as a first step toward achieving this goal by identifying 38 new sites to be added to the existing WIM station network and vehicle classification sites. The goal of the feasibility report is to identify the location needs and a budget so that the project may be programmed and funding identified for the design and construction of the WIM sites.

This project includes installation of 25 new WIM sites and the upgrading of 13 existing sites to gather traffic volume, vehicle classification, and axle weight information. Of these sites, 18 are planned as high-precision Class I Piezo Enforcement sites, while the remaining 19 will be Class I Piezo Non-enforcement sites. Each Class I Piezo Enforcement and Non-enforcement site will include a pole, foundation, solar panel, controller and pole-mounted cabinet, and cellular communications connection.

The wireless and solar equipment capabilities have evolved far enough and have been tested by the manufacturer to be adopted into the harsh Arizona climate.

ADOT Interstate 11 - Linking Sustainability and NEPA

In the summer of 2014, the Arizona and Nevada Departments of Transportation completed the two-year Interstate 11 (I-11) and Intermountain West Corridor Study. Congress recognized the importance of the portion of the Corridor between Phoenix and Las Vegas and designated it as future I-11 in the recent transportation authorization bill FAST Act, and the previous Moving Ahead for Progress in the 21st Century Act (MAP-21). The study included detailed corridor planning of a possible interstate link between Phoenix and Las Vegas, and high-level visioning for extending the corridor south to Mexico and potentially north to Canada. The I-11 and Intermountain West Corridor Study is now complete and points to the need for a new multimodal freight corridor and a manufacturing belt that will drive trade, commerce, job growth and economic development for the two states, as well as, facilitate strong connections to other major regional markets.

ADOT advertised for proposals to complete a federally funded $15 million Tier 1 Environmental Impact Study (EIS) for the proposed expanded portions of the future I-11 and Intermountain West corridor. The Tier 1 EIS is expected to take three years to complete and will start later this year. In meeting with the FHWA Division office on the scope of work for the project ADOT decided to use the FHWA developed INVEST as part of the alternatives screening for the study. INVEST is a tool to evaluate and aid the integration of sustainability into programs and projects and is one of the National Performance Objectives (SP-3) in the FHWA Performance Year 2015 Strategic Implementation Plan. With the roll out INVEST v1.2, ADOT will consider advancing innovative scope of work objectives in connection with other environmental activities as an additional format for stakeholder participation and project acceptance. ADOT also looks to inject sustainable characteristics from all three INVEST modules as the project moves from EIS, to design, to development and future operations and maintenance. This could serve as one of the first highway projects in the nation to use INVEST over a twenty year life cycle period.

Arizona Transportation Asset Management System (AZ-TAMS)

In order to provide data and information that will assist decision makers to reach appropriate performance-based conclusions affecting ADOT's own resources and various external stakeholders such as Arizona's regional councils of governments, ADOT initiated the development of the Arizona Transportation Asset Management System (AZ-TAMS). This web-based portal is an intuitive online tool for viewing and analyzing information on all aspects of the transportation system. It provides the means to develop a comprehensive performance mechanism to evaluate the overall transportation health and produces system performance measure reports that meet MAP-21 requirements.

Often, the topic of financial sustainability is not included in the traditional triple bottom line discussion. It has historically stood alone as a financial and resource management exercise. That is noticeably changing at ADOT since the reality of any sustainable transportation approach includes both life cycle cost considerations and cost benefit reasonability. According to FHWA's, Asset Management for Sustainability, Accountability and Performance, "[a]sset Management practices provide more assurance of accountability and responsibility than does merely the achievement of short-term targets. Achieving short-term targets alone does not guarantee long-term sustainability. However, when an agency selects its performance targets from among the critically important components of Asset Management processes, then the agency is far more likely to be measuring performance." Asset management has been shown to be an adaptable system which has assisted transportation agencies around the world. Its use provides agencies with a proven framework for defensible decision making. ADOT continues to develop the relationships between sustainable transportation program activities, asset management (AZ-TAMS), life cycle cost and engineering economic analysis for highway investment, and the baseline goals of practical highway design solutions. This is a multi-year, multi-faceted undertaking that aligns with the Highway Trust Fund and Federal Aid Program adoption of performance measures and deliver more-with-less approaches.

In addition, sustainability and system resilience also benefit from asset management. According to FHWA Office of Asset Management, a Transportation Asset Management Plan (TAMP) can "act as a focal point for information" about state DOT assets, their risk management strategies and business management processes, and how well yet-to-be-realized risks are being incorporated. Climate change and extreme weather has become one of those unknown risks and should be included as part of the life cycle costing and risk management framework development within a state DOT TAMP.

Considering the balance between predictable asset deterioration curves and the sudden and unpredictable nature of extreme weather impacts can serve as an important risk management component. ADOT conducted its climate change and extreme weather vulnerability assessment pilot focused on transportation infrastructure, options for adapting and improving resiliency, and contributing to a nationally recognized framework. A component of some of these pilots considers specific classes of asset vulnerability. This example further reflects how flexible a quality asset management system such as AZ-TAMS can be and how much financial sustainability underpins the current development of economic, environmental, and social efforts.

Recommendations for ADOT OM Practices

The INVEST scoring process helped ADOT identify gaps in current OM sustainability practices that present opportunities for potential improvement. Fulfillment of these recommendations would result in a higher INVEST OM score for ADOT and a correspondingly greater achievement of sustainability. These recommendations will need to be balanced and prioritized based on, for example, considerations of cost vs. value added, consistency with ADOT's concurrent programs and practices, political will, and the maturity of green technologies.

Internal Recommendations

The following recommendations are focused on ADOT's internal policies and operations:

- Develop a Comprehensive Internal Sustainability Plan, and enact an agency-wide sustainability policy led by senior executives. This plan should contain key elements including coordination, implementation, monitoring and tracking, and demonstrated progress. ADOT should also provide sustainability-related training to help the agency execute the plan.

- Provide support for alternative fuel vehicles used for commuting by ADOT employees.

- Develop a consolidated energy efficiency and use plan that includes goals for renewable energy usage and/or credits and addresses the energy reduction of ADOT facilities.

- Establish an Employee Energy Reduction Committee to promote energy savings at ADOT.

- Leverage the ADOT anti-idling policy, equipment services fuel efficiency plan, and other practices to establish a fossil fuel reduction plan for ADOT owned and operated vehicles.

- Develop a consolidated recycling plan that leverages the success of Green Shops as well as efforts at ADOT's individual facilities.

- Track facilities waste streams internally and monitor performance over time, in addition to tracking those currently performed by the State's Surplus Office.

- As a final ADOT/FHWA AZ Division Office environmental commitments tracking mechanism is developed in 2016 recommend that an environmental communications resource web page be developed similar to WashDOT.

  http://www.wsdot.wa.gov/Environment/Compliance/Construction/TrackingCommitments.htm

Maintenance Recommendations

The following recommendations are focused on ADOT's maintenance activities:

- As part of the Pavement Management System, assess the viability of High Friction Surface Treatment as a substitute for and complement to structural road fixes.

- Continue to use recently acquired software to track project timeliness as part of the Bridge Management System (BMS). The BMS should also leverage newly collected data to perform scenario analyses, trade-off analyses, and other modeling practices, as well as, perform life-cycle

cost analysis to predict costs and forecast budgets. It is anticipated that ADOT will take steps to meet this requirement once two years of data have been collected and integrated into the system.

- Improvement of the Maintenance Management System (MMS) to include automated short-term work scheduling. Integrate the MMS with FIS (this is currently underway), construction/project management systems, and a formal environmental commitment tracking system (not yet established). Use MMS to define projects and exchange information with the agency's PMS and BMS.

- Develop a consolidated Road Maintenance Plan. Integrate shoulders and sidewalks into these plans.

- Develop a formal Road Weather Management Plan with quantifiable metrics and measure progress toward those metrics.

- Implement a formal Materials Management Plan for road weather management purposes. Develop formal level of service metrics for storm performance and measure progress.

Operations Recommendations

The following recommendations are focused on ADOT's operations and programs:

- Continue developing the Safety Analyst tool to show accident prevention information for infrastructure improvements. Better incorporate this and other advanced statistical analyses used in project and program management into the monitoring process on a statewide basis.

- Develop a formal Environmental Commitments Tracking System (ECTS). This system should communicate from planning through OM, leverage tracking mechanisms, identify training needs, provide necessary reports, and employ quantifiable performance metrics. Ideally, this system would be GIS-based. It should set goals and demonstrate progress towards these goals. In order to garner credit with INVEST, use of the ECTS must be required within ADOT.

- Implement a Roadway Weather Information System in all areas identified as potentially vulnerable to severe weather conditions.

- Update dust storm warning and flooding sensors

- Leverage the late-2015 rollout of the new TSMO Division

- Continue the USGS geomorphology research effort to better rate roadside risk

- Incorporate the new FHWA Climate Change Adaptation Guide for Transportation Systems Management

- Improve the information gathering and use of post forest fire debris flows

INVEST OM Version 1.1 Feedback for FHWA

In the course of the scoring workshops, ADOT consolidated the following feedback pertaining to the INVEST program, including issues of terminology, applicability, usability, and clarity. ADOT offers the following observations and suggestions to FHWA to support the continuing evolution of the INVEST program and tool:

General/Overarching

- In several cases, ADOT has all of the elements relevant to a given criterion, but these elements are not consolidated into one document or system (as frequently required by INVEST in order to earn points). In most of these cases, ADOT personnel do not believe that consolidation of currently separate systems or platforms would add significant value or result in more sustainable outcomes. In addition, ADOT's management systems do not always align neatly with the systems defined in INVEST. The tool could allow for greater flexibility in its definition of systems and/or focus more on the anticipated *benefits* and *outcomes* of system consolidation (i.e., what is the expected value created by consolidating systems and can the same or comparable results be achieved with distinct systems?).

- While the tool defines sustainability up front, it employs the term relatively loosely within the module. Practitioners need more explicit guidance when scoring themselves on suggested goals that include the term *sustainability* (e.g., OM-01.6 – Demonstrate Sustainable Outcomes). The term sustainability may not suffice by itself; it would help if the tool more consistently employed clear and specific sustainability objectives (e.g., "fossil fuel usage reduction") and/or suggested performance measures.

Specific

- **OM-1.5a.** The travel demand management programs associated with Requirement OM-1.5a could yield substantial energy savings, fossil fuel reductions, and other sustainable outcomes; this item may warrant a greater allocation of points.

- **OM-02.3.** In OM-02.3, the term "highway facilities" should be better defined.

- **OM-02.4.** OM-02.4 might also award points for *automating* energy reduction measures (e.g., activity sensors, timers, or central controls for lights or cooling systems).

- **OM-03.1.** OM-03.1 could be worded more openly. Goals are often set for fuel *economy* rather than usage. Usage depends heavily on the number and character of projects and programs, so goals for raw usage might not adequately reflect progress toward more sustainable outcomes.

- **OM-03.2.** OM-03.2 could include language about "cost-effective" solutions. Also, agencies might have the elements of a plan but not have it consolidated into one document.

- **OM-04.** We suggest that OM-04 should be named "*Reduce*, Reuse and Recycle," rather than "Reuse and Recycle," to reflect the importance of waste reduction in any waste management strategy.

- **OM-05.** The OM-05 questions are sometimes difficult to distinguish from one another and appear somewhat redundant.

- **OM-05.5.** OM-05.5 could be more concise and explicit about the required items.

Specific continued

- **OM-06.** ADOT defines several terms used in OM-06 differently than FHWA (e.g., compliance, mitigation, commitments). The module should define "ECTS" more clearly and use examples for further clarity.

- **OM-07.5.** We suggest that the sustainability of pavements should be considered in the context of project needs, available solutions, and the efficient use of resources—not elevated to the single most important factor in the selection of treatments.

- **OM-08.3.** OM-08.3 unclearly references "two of the three metrics listed above." Please list the metrics explicitly.

- **OM-08.4.** We suggest that it is not necessary for the elements of OM-08.4 to be "cumulative" to be effective. For instance, an agency does not need to perform sophisticated modeling (OM-08.4a) to include preservation in its annual plan (OM-08.4c).

- **OM-09.1 and OM-09.3.** OM-09.1 and OM-09.3 appear very similar, at least in name. Perhaps the word "Integrate" could be removed from OM-09.1.

- **OM-09.3.** The elements in the initial textual description do not match those in the bulleted list. For example, the initial text mentions a Road Maintenance Plan, which is not a sub-criterion. Conversely, the financial management systems sub-criterion does not appear in the initial text.

- **OM-10.2b.** For OM-10.2b, a participant asked for clarification on what is considered "roadside infrastructure."

- **OM-14.** Participants suggested that some standards suggested were already required by FHWA, and that others were no longer considered state of the practice. ADOT suggest that FHWA reevaluate this criterion with the assistance of its work zone traffic control experts.

General

- Points for developing or adopting OM sustainability guidelines and metrics

- Points for developing or adopting OM sustainability training

- Points for developing or adopting OM sustainability award program

- Points for tying contractor/vendor sustainability submittals and documentation of sustainable practices to payments

- Points for maintenance activity codes that are identified as sustainable appear in the maintenance budget system

- Points for the publication of an internal and external sustainability report that includes OM

- Points for a sustainability oversight committee or "Green Team" for operations and maintenance

- Points for sustainability activities tied to Transportation Systems Management and Operations (TSMO)

General continued

- Points for creating an OM sustainability guidebook
- Points for achieving permanent soil stabilization in seeded areas by covering all exposed soil surfaces with vegetation that maintenance is responsible for
- Points for maintenance orgs to identify locations for installing bioswales (non-wildlife attracting) along roadways and parking areas to encourage groundwater infiltration of stormwater runoff
- Points for installing a closed-loop wash rack wastewater recycling system
- Points for developing and implementing sustainable landscaping guidelines/specifications that require plantings to be low-maintenance, drought resistant, and native species that are non-wildlife attracting
- Points for performing soils and climate analysis to determine the appropriate landscape strategy for projects that are slotted to exist for 50-years
- Points for commissioning requirements to ensure optimal performance of the following systems: central building automation; heating, ventilation, and air conditioning equipment; lighting controls and sensors; site lighting; refrigeration systems
- Points for agency facilities Heat Island mitigation efforts
- Points to install high reflectance/high albedo roofing materials with a high solar reflectance index.
- Points to install a Cool Roof Rating Council rated roof product or an Energy Star cool roof with equivalent reluctance and emittance properties
- OM points for Alternative Fuel Vehicles and purchase, operate and maintain alternatively fueled, electric, and hybrid vehicles
- Replace conventional gasoline-based equipment with alternative fuel based equipment, including biodiesel, compressed natural gas, hybrid electric, fuel cell, hydrogen, or liquid petroleum gas
- Points for using alternatively fueled and/or hybrid construction vehicles
- Points for providing employees with access to a hybrid and/or alternatively fueled vehicle sharing program
- Points for use of alternatively fueled ground support equipment, generators etc.

Appendix A: Sustainable Pavements Case Study

Sustainable Transportation Program

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network. The OM criteria are primarily written for the scoring of an agency's internal, system operations as well as, asset management and maintenance activities performed on the network infrastructure. The OM module contains 14 criteria and will constitutes the bulk of ADOT's 2015 sustainability efforts.

Goal

OM-07: Pavement Management System

Leverage a pavement management system to balance activities that extend the life and function of pavements with impacts to the human and natural environment.

Sustainability Linkage

Maintaining and using a pavement management system supports the environmental and economic principles by optimizing the management of pavements, including preservation, restoration, and replacement, to maximize their lifetime. This reduces costs, the environmental impacts of construction, and raw material usage.

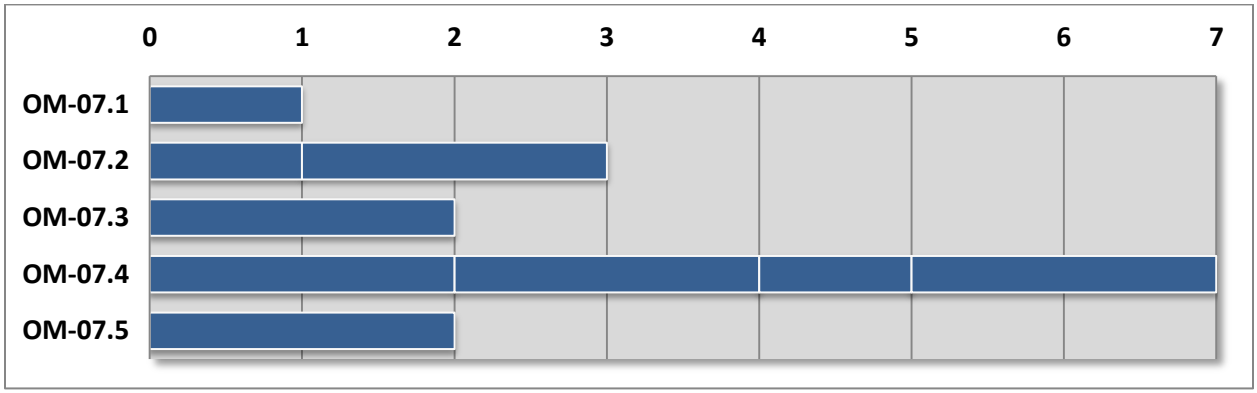
This criterion includes the following elements:

- Develop a Pavement Management System and Collect Data
- Track Pavement Network Performance
- Set Goals and Monitor Progress
- Leverage Data to Demonstrate Sustainable Outcomes
- Sustainable Specifications

Overall, ADOT views the INVEST OM Pavement Management System as contributing to sustainability by optimizing pavement life cycles to reduce costs, the environmental impacts of construction, and raw material usage.

ADOT OM-07 Performance

ADOT received all 15 points available for OM-07, and goes above and beyond INVEST goals.



-Requirement OM-07.1: Develop a Pavement Management System and Collect Data
1/1 point

ADOT has a system-wide Pavement Management System (PMS) which incorporates all required elements.

-Requirement OM-07.2: Track Pavement Network Performance
3/3 points

- *Requirement OM-07.2a: Use Common Metrics (1/1 point)*

  ADOT tracks pavement using common metrics, including IRI.

- *Requirement OM-07.2b: Measure Project Timelines (2/2 points)*

  The PMS identifies future projects and activities as well as project histories.

-Requirement OM-07.3: Set Goals and Monitor Progress
2/2 points

ADOT sets quantifiable goals for pavement condition and has monitored progress toward these goals for several years.

-Requirement OM-07.4: Leverage Data to Demonstrate Sustainable Outcomes
7/7 points

- *Requirement OM-07.4a: Leverage PMS Data to Prioritize Projects (2/2 points)*

  ADOT leverages PMS data and traffic counts to prioritize projects.

- *Requirement OM-07.4b: Leverage Life Cycle Cost Analysis (LCCA) to Predict Costs (2/2 points)*

  ADOT performs LCCA to predict short- and long-term costs every year.

- *Requirement OM-07.4c: Include Pavement Preservation in Annual Plan (1/1 point)*

  ADOT's STIP includes lump sum pavement preservation needs.

- *Requirement OM-07.4b: Link Pavement Repair, Preservation and Maintenance to Projects (2/2 points)*

  Pavement preservation and maintenance activities are linked to capital projects.

-Requirement OM-07.5: Sustainable Specifications
2/2 points

ADOT's pavement team always considers sustainable pavements for its projects. The sustainable pavements are used when they are the best option available.

ADOT Transportation Defined: Pavement Design Life

Pavement design life is a term that engineers use when they're planning to build a new road or maintain an existing roadway. They'll also use a number of years to go along with it, for example: 10-year pavement design life, 20-year pavement design life, etc.

The phrase should not be taken to imply that a road is only being built to survive for a set number of years. What it does represent is the road's age at which some preventative maintenance or reconstruction will be considered so the road can continue to be durable and useful for the traffic it's serving.

For a typical highway, ADOT generally will design asphalt pavement for 20 years. A lot is taken into consideration, soil condition, location, expected traffic levels and the area's climate. All those conditions play a role in how the pavement is designed. Say, for example, the road's being built in an area that gets very cold weather. If that's the case, engineers will adjust the asphalt pavement mix to account for the temperature extremes.

ADOT Quiet Pavement Program

One the real standout programs at ADOT is the Quiet Pavement Program. Back in the early 2000s ADOT started to hear from drivers who said certain stretches of Valley freeways seemed quieter than others. ADOT and the Maricopa Association of Governments (MAG) noticed a difference, too. It seemed that areas paved with an asphalt rubber friction course (rubberized asphalt), which MAG funded through the Regional Transportation Plan, were less noisy than freeway surfaces with cement concrete pavement. ADOT set out to determine whether the rubberized asphalt really did make any difference when it comes to noise abatement. ADOT officials also wanted to know whether the perceived noise-reducing properties of the rubberized asphalt would last as the pavement aged.

After some initial studies showed promise, ADOT, in connection with the Federal Highway Administration, developed the Quiet Pavement Pilot Program in 2003.

A three-year, $34 million project to surface about 115 miles of Phoenix-area freeways with rubberized asphalt is working toward a smoother ride for motorists and quieter neighborhoods for those who live adjacent to the roads.

The first areas to receive the "quiet pavement" were on the Loop 101 Agua Fria Freeway from Union Hills Drive to 31st Avenue, and on the Loop 101 Pima Freeway from 21st Avenue to Tatum Boulevard and from Frank Lloyd Wright Boulevard to Mountain View Road. State Route 51 was resurfaced from Shea Boulevard to Bell Road. The entire Loop 101 and SR 51 freeways plus sections of Interstate 10, Interstate 17 and the Loop 202 Red Mountain and Santan freeways will also receive new rubberized asphalt surfaces.

What Is Rubberized Asphalt?

Rubberized asphalt has been used for more than 20 years to resurface highways and city streets in Arizona when pavement surfaces reach their normal life expectancy. While it helped reduce the disposal of used tires, it recently has been recognized for its reduction of traffic noise.

Description of Rubberized Asphalt

Rubberized asphalt consists of regular asphalt paving mixed with "crumb rubber" which is ground, used tires that would otherwise be discarded or take up space in landfills. Used tires are processed by separating the casings, fabric and steel. The extracted rubber then is pulverized to the consistency similar to that of ground coffee. Rubberized asphalt has the benefit of being smoother and quieter. Noise readings have shown the rubberized asphalt generally reduces tire noise by an average of 4 decibels.

Approximately 1,500 tires are used for every lane-mile of rubberized paving, which can put a major dent in the 2 million used tires that are generated annually in Maricopa County.

Rubberized Asphalt Is Temperature Sensitive

Rubberized asphalt cannot be applied during cold weather or very hot weather. The concrete pavement surface needs to be between 85 and 145 degrees Fahrenheit for the material to adhere properly. So rubberized asphalt can only be applied in the spring and fall in the Phoenix area, from March 15 to May 31 and from September 1 to November 15. Prior to application, contractors must repair pavement cracks, chips and joints and prepare the concrete surface for the rubberized asphalt overlay.

Financing

The Quiet Pavement Program was developed by ADOT in cooperation with MAG and area cities. The completion was over a three-year period and funded using $34 million from other regional projects.

Building a Freeway: Rubberized Asphalt
http://azdot.gov/media/blog/posts/2013/07/26/building-a-freeway-rubberized-asphalt

Rubberized asphalt reduces noise, helps environment
http://azdot.gov/media/blog/posts/2011/04/21/rubberized-asphalt-reduces-noise-helps-environment

ADOT sustainable application types

Treatment	Description	Economic	Social	Environmental
Crack Filling	Placement of adhesive material	Life : Low Cost: Low	Aesthetics/Roughness	Low
Crack Sealing	Placement of adhesive material	Life : Low Cost: Low	Aesthetics/Roughness	Low
Asphalt Patching	Localized structural distress	Life : Medium/Low Cost: Medium/Low	Aesthetics/Roughness	Low Variable
Fog/Seal Rejuvenators	Very light asphalt emulsion application	Life: Low Cost: Low	Improved Aesthetics	Medium Variable
Chip Seal	Sprayed application/subsequent chips	Life : Medium/Low Cost: Medium/Low	Improved Friction/Roughness	Medium High
Slurry Seal	Mix of well-graded aggregate/emulsion	Life : Medium/Low Cost: Medium/Low	Aesthetics/Improved Friction	Medium
Microsurfacing	Crushed, well graded aggregate/emulsion/multiple course	Life: Medium/High Cost: Medium	Aesthetics/Improved Friction	Medium Variable
Hot In-Place Recycling	Heat or mechanically loosening within top 2"	Life: Medium/High Cost: Medium/High	Aesthetics/Ride Quality/Friction	Medium High
Cold In-Place Recycling	Milling and sizing reclaimed asphalt pavement (RAP)	Life: Medium/High Cost: Medium	Aesthetics/Ride Quality/Friction	Medium Variable

End of life sustainable pavement applications decision making (replacing recycled applications)

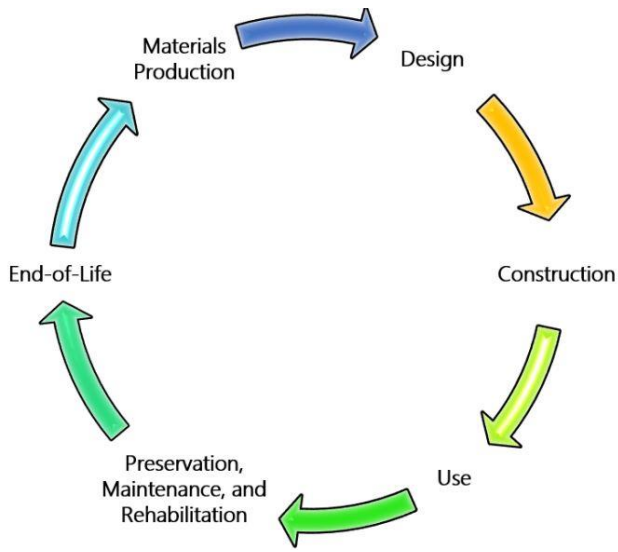
- If the pavement is extremely deteriorated and the residual asphalt content is too low then it is not a candidate for a second round of recycling with a rejuvenation agent. The only option is to Remove and Replace with newly produced AC pavement.

- If the pavement is deteriorated and the residual asphalt content is determined to be sufficient then it is a candidate for a second round of recycling with a rejuvenation agent.

FHWA Sustainable Pavements Tech Brief

In October 2014, FHWA issued a TechBrief on Pavement Sustainability (HIF-14-012)[3]. FHWA defines a sustainable pavements as one which "achieves its specific engineering goal" (i.e., meeting accepted performance standards) while meeting "basic human needs," using "resources effectively," and preserving/restoring ecosystems. FHWA notes that this is an aspirational goal to evolve toward, but is "not yet fully achievable".

Figure 2. Pavement Life-Cycle Phases (Source: FHWA)



Pavement sustainability, as defined by FHWA, is meant to involve every phase of the pavement life cycle, including 1) materials production, 2) pavement design, 3) construction, 4) use, 5) preservation, maintenance, and rehabilitation (the main emphasis of INVEST OM-07), and 6) end-of life.

FHWA notes that measuring pavement sustainability is often critical to the improvement of practices and achievement of objectives, and cites four main methods of measurement: 1) performance assessment (e.g., condition ratings, structural capacity, ride quality, etc.), 2) life-cycle cost analysis (evaluation of the "total cost of an investment over its entire life"), 3) life-cycle assessment (quantification of the environmental impacts of pavements over their life spans), and 4) rating systems, such as INVEST and Greenroads[4].

FHWA recognizes that most sustainable pavement investments will entail consideration of tradeoffs and suggests a decision-making framework that includes: 1) priorities and values of the organization or project, 2) performance ("the ability to serve an intended use"), 3) cost and benefit (focused on economic considerations), 4) impact magnitude and duration (of both positive and negative impacts), 5) risk (the degree to which the costs and/or impacts are uncertain), and 6) broad impacts in time and space (the extent to which decisions have impacts "beyond their immediate purpose").

Sustainability best practices suggested by FHWA involve "activities that result in life-cycle reductions in 1) the quantities of non-renewable resources consumed either as fuel or as direct materials, 2) the amount of greenhouse gas (GHG) emissions generated and 3) … ecological impacts." Suggested practices are organized into the following categories:

- **Materials.** Practices that aim to reduce energy and emissions while maintaining or enhancing performance. Generally, these practices a) reduce the use of virgin materials through the use of recycled, co-product, and waste materials, b) improve mix design to enhance longevity, and/or c) improve the efficiency of materials production to reduce impacts, including emissions.
- **Pavement Structural Design.** Practices include a) considering life cycle implications in decision-making, b) applying innovative pavement types and materials, and/or 3) improving structural

[3] http://www.fhwa.dot.gov/pavement/sustainability/hif14012.pdf
[4] https://www.greenroads.org/

design (leading to improvements in performance and longevity) through the application of new tools and techniques.

- **Construction Considerations to Improve Pavement Sustainability.** Practices generally focus on pavement quality, which impacts the performance and longevity across the pavement life cycle. Suggested best practices include a) allowing the use of sustainability best practices, as appropriate, b) reducing fuel consumption, energy use, and GHGs involved in construction, and/or c) improving construction quality.
- **Maintenance and Preservation Practices.** Includes practices that result in a) keeping pavements smoother for longer durations, which enables better fuel efficiency for roadway users, and b) extending the service life of pavements, resulting in material reductions over time.
- **End-of Life Considerations.** Practices that a) delay the need to repave or reconstruct (extending the usable life of pavements) and/or b) involve pavement recycling or reuse.

Next Steps for Arizona DOT

FHWA's reference document, entitled *Toward Sustainable Pavement Systems* (January 2015), elaborates and expands on these concepts and practices[5]. Although ADOT received all points available in the INVEST OM-07 scoring process, the agency recognizes that further sustainability gains can be achieved, particularly by leveraging recent FHWA research and resources. ADOT hopes to partner with FHWA to pilot a selection of suggested sustainable practices and to further recognize sustainable pavement innovations and applications by ADOT staff. The ADOT Pavement Group would like to try an Ultra-Thin Bonded Overlay (UTBO) (1/2" to 5/8") as an alternative to a ½" Friction Course in areas that have high turning movements. A Friction Course has a tendency to scrub off quickly in urban conditions. A few UTBO projects were done 10± years ago and it's time to try again.

The 2016 goal also includes the launching of a sustainable pavement systems program.

[5] http://www.fhwa.dot.gov/pavement/sustainability/hif15002/hif15002.pdf

Appendix B: Maintenance Management System Case Study

Sustainable Transportation Program

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network. The OM criteria are primarily written for the scoring of an agency's internal, system operations as well as, asset management and maintenance activities performed on the network infrastructure. The OM module contains 14 criteria and will constitutes the bulk of ADOT's 2015 sustainability efforts[6].

Goal
OM-09: Maintenance Management System

Leverage a Maintenance Management System (MMS) to inventory, assess, analyze, plan, program, implement, and monitor maintenance activities to effectively and efficiently extend the life of the system, improve the service, and reduce the impacts to the human and natural environment.

Sustainability Linkage

Utilizing an MMS supports all of the triple bottom line principles by facilitating efficient and cost-effective decision-making, better leveraging funds, improving system quality and customer satisfaction, and more effectively maintaining assets, which reduces cost and the environmental impacts of construction and raw material use.

An MMS is a computerized database that is designed to integrate an agency's asset management and maintenance management systems in order to optimize the management of maintenance. The MMS provides managers with processes, tools, and data necessary to make decisions in order to help maintenance staff do their jobs more effectively and to help management make informed decisions. This criterion includes the following elements:

- Integrate Key Elements of MMS

[6] https://www.sustainablehighways.org/917/about-the-operations-and-maintenance-module.html

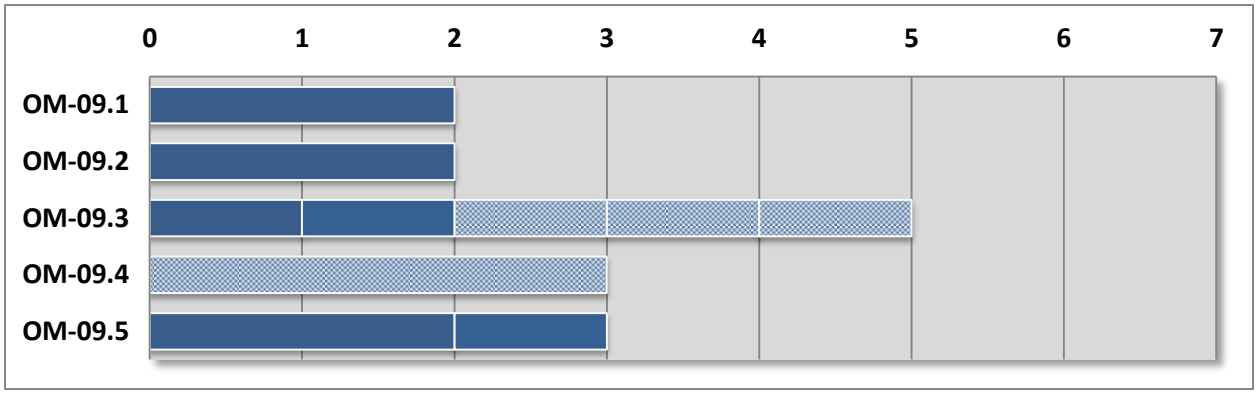
- Integrate Vehicle-Based Technology
- Integrated Maintenance Management System
- Maintenance Quality Assurance

An MMS is a computerized database that is designed to integrate an agency's asset management and maintenance management systems in order to optimize the management of maintenance. The MMS provides managers with processes, tools, and data necessary to make decisions in order to help maintenance staff do their jobs more effectively and to help management make informed decisions.

ADOT OM-09 Performance

OM-09: Maintenance Management System
9/15 points

Leverage a Maintenance Management System (MMS) to inventory, assess, analyze, plan, program, implement, and monitor maintenance activities to effectively and efficiently extend the life of the system, improve the service, and reduce the impacts to the human and natural environment.



-Requirement OM-09.1: Integrate Key Elements of MMS
2/2 points

ADOT has five of the six key elements of an MMS. The Performance Controlled System (PeCoS) serves as the maintenance performance control system. The agency employs the Feature Inventory System (FIS) for asset management and PeCoS and a predecessor system (LOS) for other planning functions including performance targets. The budget module exists outside of ADOT's maintenance management system but pulls data from PeCoS. PeCoS performs resource management tasks, work needs identification, and monitoring and evaluation, with robust reporting capabilities. Many of the maintenance support administration tasks, including risk and stockpile management, exist outside of PeCoS. ADOT's districts handle permit processing and tracking. ADOT does not have an automated short-term work scheduling module.

-Requirement OM-09.2: Integrate Vehicle-Based Technology
2/2 points

ADOT leverages vehicle-based technologies to connect to its maintenance management systems. For example, ADOT's snow plows use GPS. The agency has equipped many of its vehicles with Automatic Vehicle Locators (AVL), and uses telematics to track mileage and fuel efficiency. Drivers and equipment

operators provide end-of-shift reports that are entered into ADOT's systems. ADOT is currently equipping some of its drivers with tablets to gather more data and better manage its activities from the field.

-Requirement OM-09.3: Integrated Maintenance Management Systems
2/5 points

- *Requirement OM-09.3a: Roadway Inventory Systems (0/1 point)*

  This integration does not currently exist, but ADOT is in the process of establishing a connection between FIS and PeCoS.

- *Requirement OM-09.3b: Financial Management Systems (1/1 point)*

  ADOT's maintenance management system includes a financial module.

- *Requirement OM-09.3c: Construction/Project Management Systems (0/1 point)*

  This integration does not currently exist.

- *Requirement OM-09.3d: Equipment Management Systems (1/1 point)*

  ADOT's maintenance management system automatically pulls equipment management information.

- *Requirement OM-09.3e: Environmental Commitment Tracking System (0/1 point)*

  ADOT lacks a formal environmental commitment tracking system and its maintenance management system does not automatically access relevant environmental commitment information.

-Requirement OM-09.4: Leverage MMS to Define Projects
0/3 points

ADOT's maintenance management system is not fully integrated with its pavement and bridge management systems, though information is shared manually.

-Requirement OM-09.5: Maintenance Quality Assurance [MQA]
3/3 points

- *Requirement OM-09.5a: MQA Relates Maintenance to Performance (2/2 points)*

  ADOT's LOS (Level-of-Service) system relates highway maintenance activities to performance.

- *Requirement OM-09.5b: MQA Used to Understand Relationship between Costs and Outcomes (1/1 point)*

  The LOS system helps the agency develop strategies (such as preventative maintenance), set priorities, and document the relationship between costs and outcomes.

Further Discussion of Requirement OM-09.1: Integrate Key Elements of MMS

As of ADOT fiscal year 2016 a complete overhaul was undertaken to truly develop a systematic, database-linked, needs-based budget allocation process. First, what is a needs-based model and why did ADOT undertaking this effort?

- Moving Ahead For Progress in the 21st Century Act (MAP-21)
    - Required to Establish a Performance Based Program
    - Federal Funds Tied to Achieving Performance Targets
    - Asset Management (New ADOT Asset Mgmt Engineer)

- Increase Accountability of Budget Allocation Process
    - Specific Line Item in State Budget
    - Identified In Sunset Audit Findings
    - District Performance Tied to Targets Established by SEO
    - Follow Measures Expected in MAP-21

Needs-based budgeting is a repeatable process that organizations use to rigorously review every dollar in the annual budget, manage financial performance on a monthly basis, and build a culture of cost management among all employees. It is a sustainable alternative to historic need cost management.

During the initial setup, a central coordination team led by a Maintenance Management Administrator, developed the needed costs and data sets that would be used for the next budgeting cycle. The team also worked on common sense systems and processes for the detailed reporting, governance, and performance management requirements. The setup phase itself served to develop a comprehensive cost-management tool kit – that included governance, accountability, visibility, aligned incentives, and a rigorous process check and balance exercise.

Terms, conditions, and definitions had to be identified so participants could use a standardized language.
Group – Level of Service (LOS) Categories
(Roadside, Vegetation, Landscape, Paved Services, Traffic)

Feature – Measurable Items Being Assessed
(Fence, Cracking, Impact Attenuators, Irrigation, Striping, ROW, etc.)

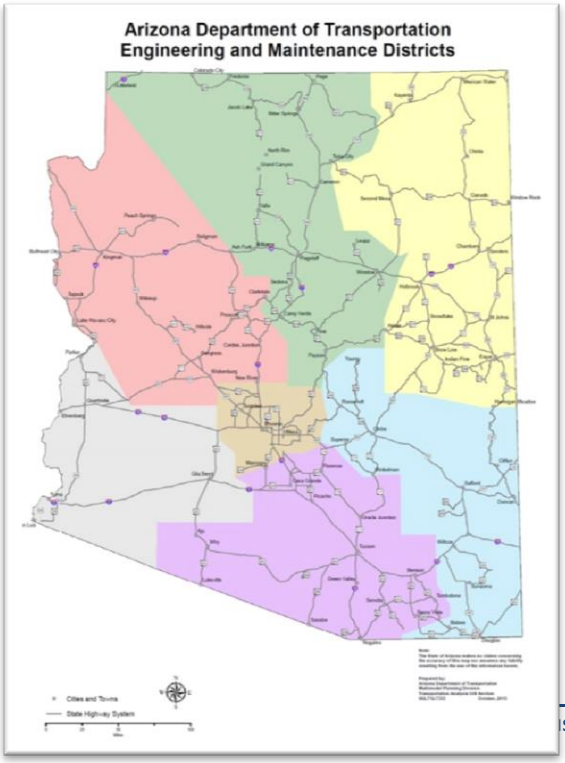
Activity – Work Being Performed on Features
(Fence Maint, Guardrail Repair, Hydroseeding, Sign Maint, etc.)

Performance Targets –Desired Feature LOS Scores as Defined by the State Engineer's Office

Activity Assumption Assignment – Percentage (%) of Activity Work That Can be Applied Towards the Improvement of a Feature

A Flow model was developed for ease of communication

Maintenance Management Core Elements



Activity Goals of the Project

ADOT must manage almost 30,000 maintenance lane miles broken out among seven (7) engineering and maintenance districts (at left). It has resources allocation responsibilities for about $150 million dollars in State of Arizona and Regional Transportation Program funds. Historic allocation mechanisms were not properly accounting for scarcity of funds and true needs-based realities. The effort was focused on pushing resource funds out to those districts as opposed to traditional pull dynamics.

There existed 250 maintenance activities in the PeCoS system all reasonably geared toward a specific transportation asset feature. The feature data was simultaneously going through an upgrade through ADOT's FIS. The fact remained that with seven different districts there existed seven different ways of doing things. In order for the new model to work the needs-based process

had to be rooted in developing the assumption for revised resource allocation from those 250 activities. The needs-based component developed its base level in connection with the district maintenance labor time allocated to each of the 250 activities.

The PeCoS Planning tool was originally not used in its current manner, and languished as it remained untethered to other relevant databases. The agency mindset had to change. It could no longer be what-you-think/what-you-want but had to morph into what-is-your-need based on a specific plan - therefore, becoming *needs-based* instead of the traditional annual budget allocation basis plus or minus an amount. The State Engineer's Office sets targets for every feature and every district. The foundational premise was rooted in what estimates were established when the system was first built. Of course for a *needs-based* system to flourish updated activity determinates had to be developed. Hence, the first year pilot effort would also serve as the baseline determinant exercise. The risk level tied to those determinates boiled down to what level of deficiency or level of service was the SEO willing to accept for each of those 250 activities. PeCoS consists of:

- Guidelines for 250+ Maintenance Activities
- Records 100% Maintenance Funds
- Documents Maintenance Work Performed
- What work was performed and where?
- Who performed the work?
- What equipment, materials and other resources were used?
- What was the cost?
- Manage Material Inventories
- Dedicated Support of Seven (7) Staff

In order to normalize those determinants and tie the 250 activities to a standard performance metric that existed in PeCoS a cost-per-accomplishment was established. From there targets could be set.

PeCoS - Entry of work for each activity → Update Feature Inventory System (FIS) that each activity was performed on → against a level of service the SEO set for that feature → sum total of all these actions creates district level annual work quantities → from there next year targets can be set grounded in the need established by the recorded PeCoS activities.

Going forward, a wider group of data sets will be integrated to allow for wider consideration of what districts are faced with each year.

- Human Resources
- Accounting
- Equipment Services
- MMSP (Org Boundaries)
- Maintenance Unit Database
- Heavy Equipment Motor Pool

- Automatic Vehicle Locator
- ProcureAZ (New)
- Feature Inventory System
- Level of Service

To further clarify the SEO LOS evaluation, deficiency risk was broken down by the following:

- Evaluations Focused on Measurements and Counts
- Provides consistencies across State
- LOS evaluations not based on inspector experience
- Simplifies quality assurance efforts
- Evaluations Identity Specific Deficiencies
- Based on a Grading Scale – A+ to F for three categories

Roadway

Traffic

Landscape

Next Steps for Arizona DOT

Currently the specific targeted activities are just over 50% verified that the complete flow is working. The target by the end of 2016 is validating 85%. In addition, non-target activities are on the short list for integration, electric, signals, tunnels, rest areas, and snow to mention a few.

Appendix C: ADOT Sustainability & Transportation System Management & Operations (TSMO)

Sustainable Transportation Program

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network. The OM criteria are primarily written for the scoring of an agency's internal, system operations as well as, asset management and maintenance activities performed on the network infrastructure. The OM module contains 14 criteria and will constitutes the bulk of ADOT's 2015 sustainability efforts[7].

OM-13 Goal

Maximize the utility of the existing roadway network through use of technology and management of operations strategies.

Sustainability Linkage

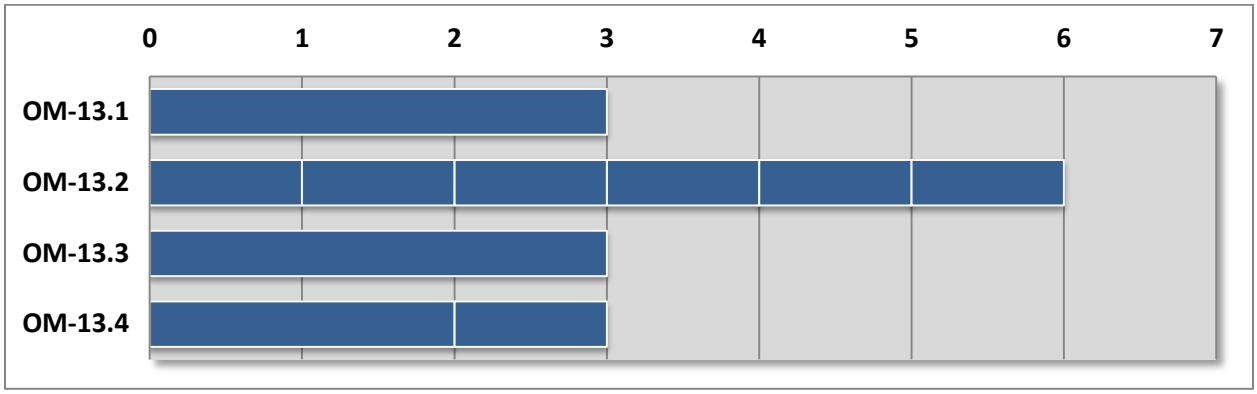
Transportation management and operations support all of the triple bottom line principles. More efficient operations of the roadway network will result in a reduction of fossil fuel usage and related emissions. In addition, a reduction in the number and severity of crashes can be realized. Therefore, congestion and private and public property loss, injury, and loss of life; and a reduction in the resources and related costs needed to expand capacity of the network can occur.

ADOT OM-13 Performance

OM-13: Transportation Management and Operations
15/15 points

Maximize the utility of the existing roadway network through use of technology and management of operations.

[7] https://www.sustainablehighways.org/917/about-the-operations-and-maintenance-module.html



-Requirement OM-13.1: Conduct Enhanced or Expedited Compliance
3/3 points

ADOT has instituted enhanced transportation management and operations measures, particularly in the Phoenix metropolitan area.

-Requirement OM-13.2: Include Operation-Based Programs and Develop Performance Measures
6/6 points

Based on an interview with ADOT's traffic control group, the agency has implemented at least one ITS technology in at least seven different categories (defined by INVEST),

-Requirement OM-13.3: Integrate Operations Strategies and Projects into Systems Planning and Establish Performance Goals and Monitor Progress
3/3 points

ADOT integrates operations strategies and projects into systems planning and selectively establishes performance goals and monitors progress.

-Requirement OM-13.4: Set Goals and Monitor Progress
3/3 points

- *Requirement OM-13.4a: Establish Safety and Mobility Performance Metrics (2/2 points)*

  ADOT has at least one safety and one mobility performance metric relevant to the implementation of ITS solutions.

- *Requirement OM-13.4b: Monitor Progress and Demonstrate Sustainable Outcomes (1/1 point)*

ADOT monitors progress towards transportation management and operations goals for at least one year and shows advancement.

Transportation System Management & Operations (TSMO) – Federal Highway Administration

As congestion spreads and intensifies and the level of incidents, delays, and disruptions increase, the level of service and reliability of the roadway systems in many areas continues to deteriorate. Given the constraints on the provision of significant new capacity, it is increasingly important to operate the existing network to its fullest service potential, especially "taking back" the capacity lost to congestion, incidents, construction, weather, poor signalization, etc. The contribution of these problems to congestion is shown in Figure 1.

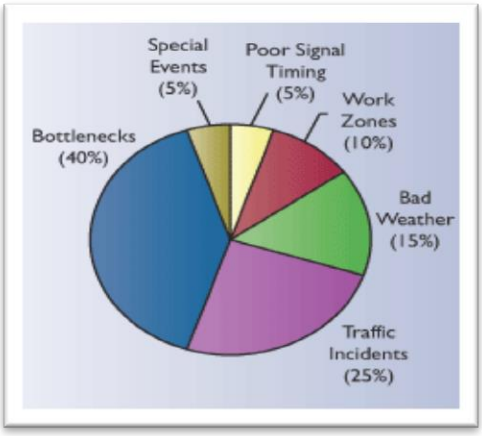


Figure 1. Sources of Congestion

TSMO offers the potential to provide an integrated program to optimize the performance of existing infrastructure through the implementation of specific systems and services that preserve capacity and improve reliability and safety. The TSMO activities focus on a set of well-known strategies such as incident management, traffic signal timing, ramp metering, road weather management, and others.

TSMO – Arizona DOT

A new TSMO Division launched on October 1, 2015. The TSMO Division will lead ADOT's efforts in Traffic Incident Management, Incident Corridor Management and Emergency Management, as well as, being the agency's lead in the areas of Signal System Coordination and Connected and Automated Vehicle research and implementation.

This TSMO Division structure includes a centralized administrative model that will promote transparency and provide opportunities for career advancement. In addition, it will allow for seamless cross pollination of administrative staff. The oversight and management of the Maintenance Appropriation will reside in the office of the Deputy Director for Transportation.

ADOT recognized the importance of extracting the greatest efficiencies out of the system it was operating. The continued rotation from infrastructure expansion to a maintenance and preservation approach, emphasis in programs such as sustainability and TSMO, allows for a more programmatic approach since the focus is rooted in extracting efficiencies and best management practices. With the release of FHWA's *Climate Change Adaptation Guide for Transportation Systems*, TSMO and sustainability links are further identified. The guidebook identifies co-benefits of integrating specific adaptation strategies into TSMO programs. Generally, co-benefits are assessed at a qualitative level in order to help identify "win-win" strategies that increase program objectives getting done. Often, it is easier to obtain support for funding these types of solutions because they accomplish multiple goals.

Some examples of where sustainability and TSMO co-benefit include:

- Greenhouse gas mitigation
- Decreased operating costs
- Increased roadway safety

- Sustainability (i.e., improvements to the economy, environment, or social equity)
- Improvements in other performance measures

TSMO, INVEST & Climate Change – Further Discussion

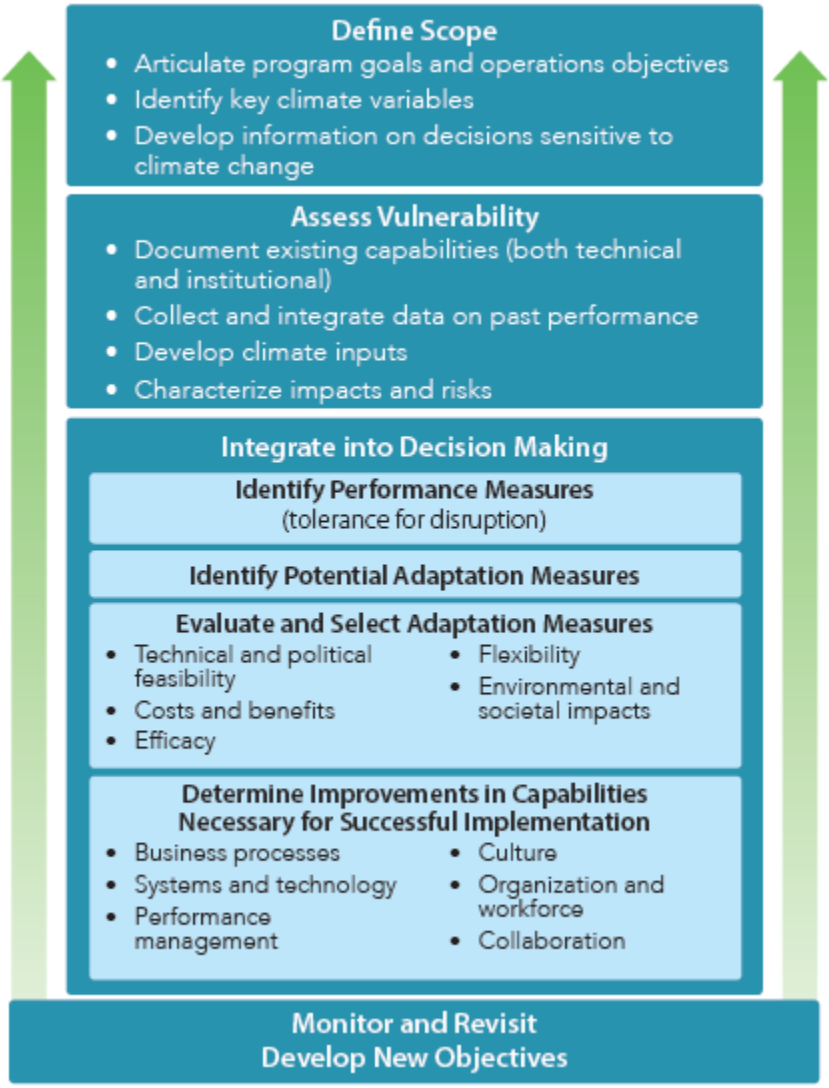
The flexibility of INVEST is never more evident than how TSMO resides across all the INVEST modules; from Innovative Criteria, IN-01 through IN-03, new criterion accommodating innovative and emerging sustainability practices not covered in INVEST; to the revised SPS-14: Transportation Systems Management & Operations that adds Road Weather Management to the list of TSMO Strategies; to SPS-16: Infrastructure Resiliency.

As referenced on the prior page, the FHWA Office of Operations has completed the first climate change document that addresses what transportation systems management and operations, maintenance and emergency management staff need to consider with regard to climate change. According to FHWA, the *Climate Change Adaptation Guide for Transportation Systems*;

> Provides information and resources to help transportation management, operations, and maintenance staff incorporate climate change into their planning and ongoing activities. It is intended for practitioners involved in the day-to-day management, operations, and maintenance of surface transportation systems at State and local agencies. The guide assists State departments of transportation (DOTs) and other transportation agencies in understanding the risks that climate change poses and actions that can help reduce those risks. Incorporating climate change considerations into how agencies plan and execute their transportation system management and operations and maintenance programs helps the agency become more resilient to unanticipated shocks to the system. Adjustments to TSMO and maintenance programs—ranging from minor to major changes—can help to minimize the current and future risks to effective TSMO and maintenance.

Take Action to Increase Resilience http://ops.fhwa.dot.gov/publications/fhwahop15025/index.htm

TSMO and maintenance functions at DOTs are often responsive to conditions as they arise. There are nevertheless some activities that, if done in advance, can enhance the resilience of the transportation system overall and with greater efficiency to the public agency than if actions had not been taken. Adapting TSMO and maintenance programs is largely about improving capability rather than a major technology development and deployment initiative. Many of the technology elements used to support safety, congestion mitigation, and traveler information objectives are already in place. To adapt to climate change, agencies need to consider how these existing capabilities that already help to improve operations and reliability need to evolve to meet the new and emerging requirements of a changing climate.



The framework above, from the guidebook, provides an overview of how TSMO and maintenance managers can begin to take action through steps to: define the scope of adaptation efforts; assess vulnerabilities to inform the development of adaptation strategies; and integrate climate change into decision-making.

Next Steps

ADOT is many years into vulnerability assessment and resilience building due to its variable climate and weather. As the new ADOT TSMO division develops this guidebook creates an opportunity for much faster adoption of appropriate adaptive measures. Developing extreme weather approaches that are both reasonable and beneficial can take years, the comprehensive effort undertaken on this guidebook shortens that adoption time considerably. ADOT TSMO management has been provided the guidebook and reference tools and 2016 should see initial discussions develop.

Appendix D: Sustainability and the Arizona Strategic Highway Safety Plan Case Study

Transportation Program

Affected Triple Bottom Line Principles Sustainable

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network. The OM criteria are primarily written for the scoring of an agency's internal, system operations as well as, asset management and maintenance activities performed on the network infrastructure. The OM module contains 14 criteria and will constitutes the bulk of ADOT's 2015 sustainability efforts[8].

Goal

OM-05 Safety Management

Maximize the safety of the existing roadway network through a systematic and comprehensive review of safety data and the allocation of resources in planning and programming to support safety in operations and maintenance.

Sustainability Linkage

Reducing fatal and serious injuries contributes to the social and economic principles by reducing the impacts associated with personal and public property damage, injury, and loss of life. This criterion includes the following elements:

Assess Current Safety Performance

Set Goals and Targets

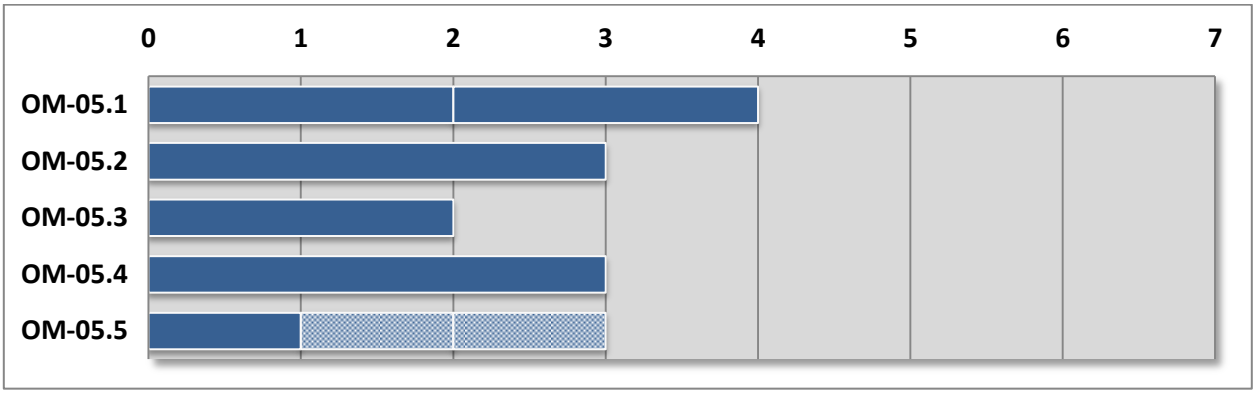
Develop a Plan

Implement the Plan

[8] https://www.sustainablehighways.org/917/about-the-operations-and-maintenance-module.html

OM-05: Safety Management
13/15 points

Maximize the safety of the existing roadway network through a systematic and comprehensive review of safety data and the allocation of resources in planning and programming to support safety in operations and maintenance.



Requirement OM-05.1: Assess Current Safety Performance
4/4 points

- *Requirement OM-05.1a: Evaluate Safety Performance (2/2 points)*

  The Strategic Highway Safety Plan (SHSP) evaluates safety performance across twelve different crash types. These crash types include behavioral categories, such as unbelted crashes.

- *Requirement OM-05.1b: Identify Safety Performance Metrics (2/2 points)*

  The SHSP has performance metrics for each crash type, including behavior-related metrics that reflect the portion of overall crashes where these behaviors are present.

Requirement OM-05.2: Set Goals and Targets
3/3 points

- *Requirement OM-05.2a: Set Safety Goals (2/2 points)*

  ADOT's SHSP sets long-term and intermediate safety goals. Individual teams set targets for each category. Several targets would require external laws, regulations, and policies, such as the state legislature passing a primary seatbelt law or motorcycle helmet law.

- *Requirement OM-05.2b: Integrate Safety Goals with Maintenance and Operations (1/1 point)*

  When funding is available, safety goals are effectively integrated into these activities. The safety team remarks that safety goals are an element of but not the be-all and end-all of ADOT's new planning-to-programming (P2P) initiative.

Requirement OM-05.3: Develop a Plan
2/2 points

- *Requirement OM-05.3a: Develop a Statewide Safety Plan (1/1 point)*

  The SHSP fulfills this requirement.

- *Requirement OM-05.3b: Include Strategies and Activities to Support Improvement of Data and Analysis (1/1 point)*

  The SHSP stresses the importance of data management and analysis and has its own data improvement element. The agency is working to improve its data inventory and is in the process of integrating its safety data into GIS. ADOT uses a tool called Safety Analyst to integrate local data into one platform.

Requirement OM-05.4: Implement the Plan
3/3 points

ADOT implements its SHSP in an integrated and multidisciplinary manner and addresses all of the criterion's required elements.

Requirement OM-05.5: Measure Progress and Monitor Performance
1/3 points

ADOT uses Safety Analyst to measure progress and monitor performance, but not on a statewide basis. The department uses advanced and statistically sound performance evaluations on a project basis. The Safety Analyst tool should help ADOT to expand the scope of monitoring activities to cover the entire State system in the future.

Arizona Strategic Highway Safety Plan

Federal regulations require all states to have a Strategic Highway Safety Plan (SHSP) that provides a comprehensive framework for reducing fatalities and serious injuries on public roadways. The state's Department of Transportation leads development of its SHSP in cooperation with local, state, federal and other safety stakeholders. Under the completed SHSP, all highway safety programs in the state can leverage resources and work together to address transportation safety issues.

In August 2014, the Arizona SHSP Executive Committee approved the Arizona 2014 Strategic Highway Safety Plan. The SHSP is developed by the Arizona Department of Transportation in cooperation with local,

regional, state, federal, tribal, non-profit and private-sector safety stakeholders. The SHSP is a data-driven, multiyear plan that establishes statewide goals and objectives and identifies Emphasis Areas that must be addressed to reduce traffic fatalities and serious injuries. The plan outlines feasible strategies and action steps or countermeasures to address the Emphasis Areas through integration of the 4 E's of transportation safety: Engineering, Education, Enforcement and Emergency Medical Services. Arizona's 2007 SHSP The previous Arizona SHSP was adopted in 2007 and, since then, significant reductions in fatalities and serious injuries have been observed. With the 2007 plan, Arizona established a long-term state vision of "Zero fatalities on Arizona roads, your life depends on it" and "No fatalities by 2050." The plan also included an intermediate goal of a 12 percent reduction in the number of fatalities in the first five years, and a stretch subgoal in each Emphasis Area category of reducing fatalities by 15 percent during the five-year period. By the end of 2012, reductions in fatalities in Arizona had exceeded the state safety goal, as fatalities decreased overall by 23 percent. In addition, the 15 percent stretch subgoal for each Emphasis Area was exceeded: Restraint Usage (29%); Young Drivers (34%); Speeding (34%); Impaired Drivers (26%); Roadway Lane Departure (25%); and Roadway Intersection Related (26%).

Arizona's 2014 SHSP

In late 2012, Arizona's safety leaders began the process to update the SHSP in accordance with the new federal regulations outlined in legislation that funds the federal surface transportation programs, Moving Ahead for Progress in the 21st Century Act (MAP-21). The purpose of the SHSP update is to direct transportation-project investment decisions and assure best practices are adopted to achieve a significant reduction in transportation related fatalities and serious injuries on all public roadways. The SHSP update process was a collaborative effort involving safety stakeholders, transportation safety research, and extensive analysis and documentation of the statewide database of crash records and other data. The data analysis included geospatial investigation of crash characteristics associated with all fatal and serious-injury crashes and the relationship or interaction of these crashes between the various summarized crash characteristics. These efforts helped to identify 12 safety Emphasis Areas and two support areas, as well as identify and prioritize safety strategies. The Executive Committee recommended focusing especially on five Emphasis Areas that are associated with the highest number of fatalities and serious injuries. Focus on these Emphasis Areas is expected to have the greatest impact in reducing fatalities and serious injuries. This process established a new vision that encompasses and focuses on all safety efforts in the state.

Attached you will find a comprehensive case study showing an example of how the SHSP is operationalized at the system level with Publication No. FHWA-HIF-15-014 (See P.1-17 next).

Publication No. FHWA-HIF-15-014

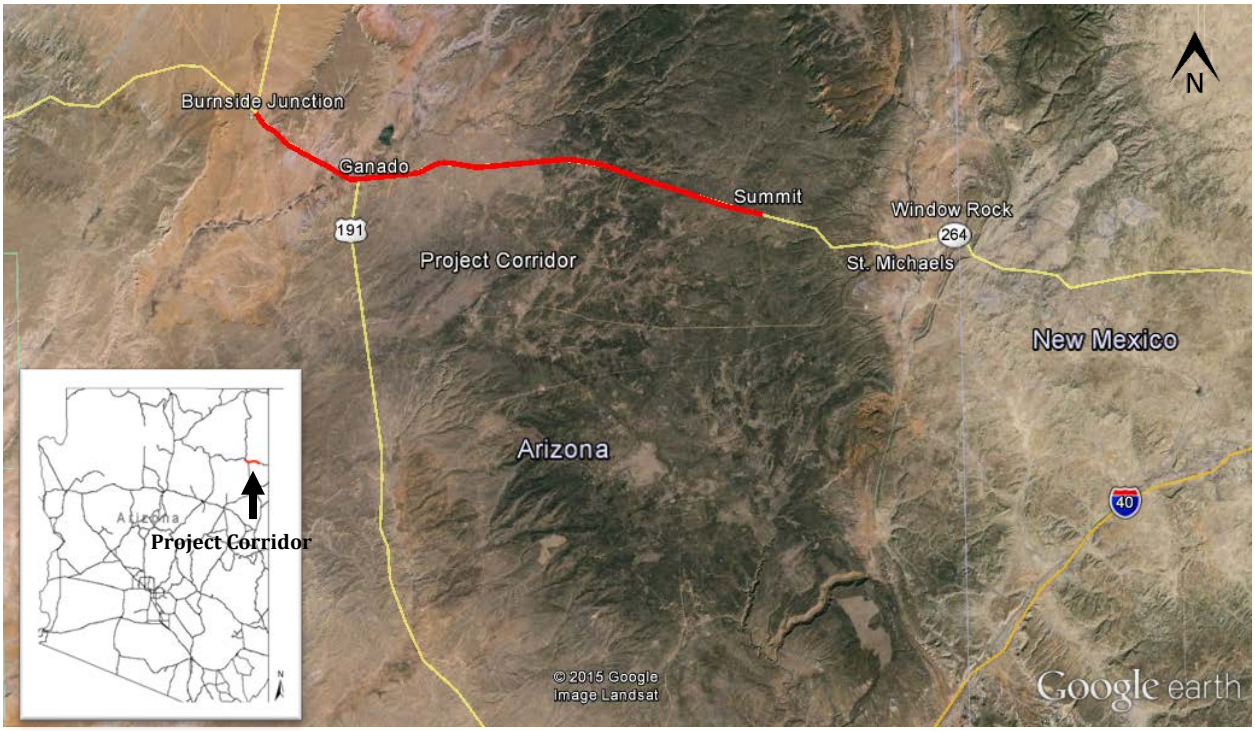
Case Study: Arizona SR 264 Burnside Junction to Summit - Safety Improvement Evaluation

Agency: Arizona Department of Transportation (ADOT)
Location: Navajo County, Arizona
Region: Southwest Region
Setting: Rural

Overview

The Arizona Department of Transportation (ADOT) Traffic Safety Section recognized that a significant portion of Arizona's fatal crashes were of the run-off-roadway crash type along rural two-lane highways, as is typical for most states with significant mileage of rural highways. The ADOT Traffic Safety Section took a systemic approach and reviewed two-lane rural highways with a higher potential for run-off-roadway crashes. One of the priority corridors for shoulder widening as a federal Highway Safety Improvement Program (HSIP) funded project was State Route 264 (SR 264) from Burnside Junction to Summit in Northern Arizona. This is a 24.55 mile corridor from Milepost (MP) 441.19 in Burnside Junction to MP 465.74 at the Summit. This section of SR 264 is located in Navajo County, Arizona, within the ADOT Holbrook District and is shown in Figure 1. SR 264 through this section is classified as a rural minor arterial and runs east-west. The area of interest is currently a two-lane rural highway, with intermittent right- and left-turn lanes and passing lanes.

Figure 1 – Vicinity Map



Source: Google Earth

Performance-Based Practical Design is a decision making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources. Performance-Based Practical Design can also be articulated as modifying a traditional design approach to a "design up" approach where transportation decision makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. Performance-Based Practical Design uses appropriate performance-analysis tools, considers both short and long term project and system goals while addressing project purpose and need. The following case study on SR 264 in Arizona is an example of developing a performance-based practical design for the shoulder width and project segmentation.

During the project scoping evaluation by the ADOT Traffic Safety Section, it was determined that the project would be split into two separate segments which are intended to be prioritized based on the potential reduction of the total number of crashes. The mile post (MP) limits of the two segments are as follows:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

Using the American Association of State & Highway Transportation Officials (AASHTO) Highway Safety Manual (HSM), 2010, Predictive Method, expected total crashes were estimated for the purpose of evaluating the effect of:

- Design alternatives; and
- Segment Prioritization

The effect on traffic safety was analyzed for the following improvement alternatives:

- Shoulder Widening Alternative A - Widening the existing 1-foot shoulders to 5 feet;
- Shoulder Widening Alternative B - Widening the existing 1-foot shoulders to 8 feet; and
- Improving superelevation to bring into compliance with AASHTO recommendations.

The following provides a summary of the three traffic safety alternatives:

Shoulder Widening Alternative A – Widen Existing Roadway to 34 feet

The purpose of Alternative A is to widen the existing roadway to 34 feet to provide 5-foot shoulders. The proposed improvements would widen the existing 1-foot shoulders to 5-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures and providing delineators and recessed pavement markers. The original intent was for this alternative to be 32 feet wide with 4-foot shoulders; however it was widened to 5-foot shoulders to be able to meet the FHWA recommendation for a 4-foot bikeable width outside of the rumble strip.

Shoulder Widening Alternative B – Widen Existing Roadway to 40 feet

The purpose of Alternative B is to widen the existing roadway to 40 feet to provide the standard shoulder width. The proposed improvements would widen the existing 1-foot shoulders to 8-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures, and providing delineators and recessed pavement markers.

Superelevation Improvement Consideration

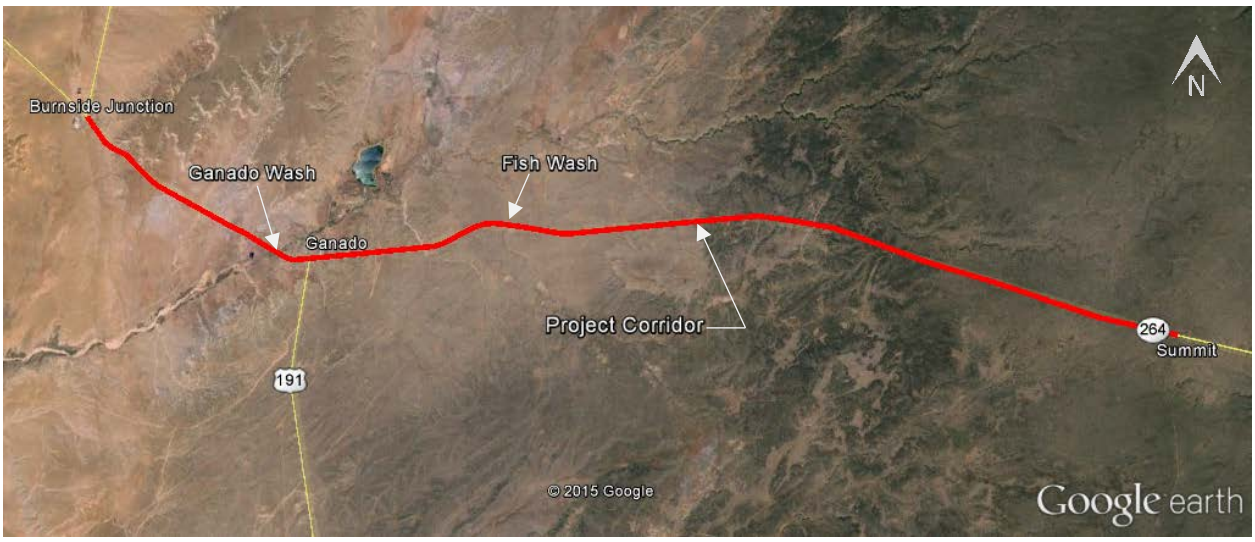
An additional consideration is to improve the superelevation on horizontal curves located within the project limits to bring the cross slope into compliance with the AASHTO recommended minimum superelevation rates. The superelevation improvements were evaluated independently of any additional improvements for the purpose of developing a benefit-cost ratio.

Approach

Analysis of Existing Conditions

SR 264 is an undivided highway consisting of one 12-foot travel lane in each direction with approximate 1-foot paved shoulders on each side. Climbing lanes are present for eastbound travel between MP 441.2 and MP 442.6, westbound travel between MP 442.6 and MP 443.8, and eastbound travel between MP 447.6 and MP 448.8. There are existing turn lanes at MP 446.3, 446.6, 446.9 (US 191), 448.3 and 452.1. There are four major structures located within the project limits including one structural plate pipe arch, one pedestrian overpass, and two bridges at Fish Wash and Ganado Wash. There is existing guardrail at Ganado Wash Bridge (MP 446.20), at MP 447.0, and at Fish Wash Bridge (MP 451.30). An aerial view of the location of interest is shown in Figure 2.

Figure 2 – Aerial View of Project



Source: Google Earth

As reported by the Data Team of the Multimodal Planning Division (MPD), the 2010 Average Annual Daily Traffic (AADT) within the project limits varies between 4,100 and 6,500 vehicles per day as shown in Table 1.

Table 1: 2010 AADT

SR 264	2010 AADT (vehicles per day)
MP 441.02-MP 446.18	5,010
MP 446.18-MP 446.91	6,429
MP 446.91-MP 448.37	5,199
MP 448.37-MP 475.50	4,102

Crash data for the most recent 4-year period (2007-2010) were used in this evaluation since 2011 crash data was not available to use at the time of this study. Tables 2 and 3 below summarize the total number of crashes, as well as the severity and manner of collision.

Table 2: Crash Severity, 2007-2010

Severity	Number
Fatal	6
Incapacitating Injury	3
Non-Incapacitating Injury	1
Possible Injury	24
No Injury (PDO)	22
Total	*56*

Table 3: Manner of Collision, 2007-2010

Manner of Collision	Number
Head On	2
Left Turn	3
Rear End	13
Angle (Other than Left Turn)	5
Sideswipe (Opposite Direction)	2
Sideswipe (Same Direction)	4
Single Vehicle	27
Total	*56*

A total of 56 crashes were found to be associated to SR 264 within the project limits between 2007 and 2010. The average annual crash frequency is 14 crashes per year.

As reported by the Data Team of the MPD, the 2036 Projected AADT for SR 264 within the project limits varies between 5,400 and 12,150 vehicles per day as shown in Table 4.

Table 4: 2036 Design Year AADT

SR 264	2036 Projected AADT (vehicles per day)
MP 441.02-MP 446.18	9,900
MP 446.18-MP 446.91	12,150
MP 446.91-MP 448.37	7,350
MP 448.37-MP 475.50	5,400

A safety analysis was performed by ADOT's consultants for this project using the procedures outlined in the *Highway Safety Manual* (HSM). The HSM provides guidance on how to analyze highway sections that are reasonably homogeneous with respect to key variables such as traffic volume, highway cross-section, highway classification, and surrounding geometric conditions. The proposed improvements are not anticipated to impact traffic operations, since all alternatives have one travel lane in each direction. Therefore a traffic operational analysis was not performed for this study.

Safety Analysis

Implementation of the Predictive Method requires the development of three main parts: a Safety Performance Function (SPF), Crash Modification Factors (CMFs), and a local calibration factor (C). The SPF uses roadway geometry, roadway characteristics, and traffic conditions to determine a base condition for a particular category of highway. For the purpose of this study, SR 264 falls under the category of a rural two-lane, two-way road as defined in Chapter 10 of Part C of the HSM. CMFs are then applied to the SPF to create a site-specific function that more accurately reflects the existing or proposed conditions of the roadway. Finally, a calibration factor can be applied to account for jurisdictional/regional variations in climate, driver population, etc. At the time of this study, ADOT has not developed a local calibration factor. So, a local calibration factor was not applied.

Table 5 shows the base parameters of the SPF for a Rural Two-Lane, Two-Way Road along with the parameters used in developing the SPF for the existing and proposed conditions. Notable variations from the base condition include the shoulder width, roadside hazard rating, and centerline rumble strips.

Table 5: Base Parameters for the SPF for Rural Two-Lane, Two-Way Road

Roadway Element	Existing SR 264 (1 foot Shoulder)	HSM Base Condition	Alternative A (5 foot Shoulder)	Alternative B (8 foot Shoulder)
Lane width	12 feet	12 feet	12 feet	12 feet
Shoulder width	1 foot	6 feet	5 feet	8 feet
Shoulder type	Paved	Paved	Paved	Paved
Roadside hazard rating	6	3	2, except 4 for guardrail sections	2, except 4 for guardrail sections
Driveway Density	Per survey & Holbrook District turnout database	≤ 5 per mile	Per survey & Holbrook District turnout database	Per survey & Holbrook District turnout database
Horizontal curves: length, radius, and presence or absence of spiral transitions	Per best-fit alignment	None	Per best-fit alignment (match existing)	Per best-fit alignment (match existing)
Horizontal curves: Superelevation	Per as-builts & survey	None	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Grades	Per as-builts & survey	≤ 3%	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Centerline rumble strips	None	None	Present	Present
Passing lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Two-way left-turn lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Lighting	Present @ US 191 Intersection	None	Present @ US 191 Intersection (match existing)	Present @ US 191 Intersection (match existing)
Automated speed enforcement	None	None	None	None

Utilizing the Interactive Highway Safety Design Model (IHSDM) software and the parameters listed above, the Predictive Method was applied to each alternative to calculate a predicted total number of crashes for the study period of 2016 to 2036. An expected total number of crashes was calculated by including site specific crash data in the predictive analysis using the Empirical Bayes (EB) Method.

Existing Conditions with Projected AADT Values

Using the methodology detailed above, an expected total number of crashes was calculated for SR 264 from Burnside Junction to Summit, as shown in Table 6.

Table 6: Existing Conditions Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes
Total	636.38
Fatal and Injury (FI)	283.40
Property Damage Only (PDO)	352.98

The expected total number of crashes over the 20-year analysis period is 636.38 crashes, which equates to a crash frequency of 31.82 crashes per year.

Analysis of Roadside Design Alternatives

Proposed Conditions with Projected AADT Values

Using the same methodology as before, an expected number of crashes was calculated for SR 264 for each of the alternatives previously mentioned and is summarized in Table 7.

Table 7: Expected Crashes with Proposed Shoulder Widening

Crash Severity Level	2016 2036 Expected Total Number of Crashes		
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders
Total	636.38	531.58	504.16
Fatal and Injury (FI)	283.40	230.45	216.80
Property Damage Only (PDO)	352.98	301.13	287.36
Reduction in Total Crashes over Existing Conditions	-	104.80	132.22

The proposed improvements for alternatives A and B respectively reduce the expected number of crashes compared to the existing conditions by 104.80 and 132.22 crashes over the 20-year analysis period. The corresponding Crash Modification Factors (CMFs) for Alternatives A and B are approximately 0.84 (16% reduction) and 0.79 (21% reduction), respectively.

Superelevation Improvements with Projected AADT Values

The Predictive Method was also used to evaluate the effect of improving superelevation rates on the total expected number of crashes. The analysis was performed assuming that the superelevation improvements were being made independent of all other improvements. The results of the superelevation analysis are shown in Table 8.

Table 8: Expected Crashes with Proposed Superelevation

Crash Severity Level	2016 2036 Expected Total Number of Crashes	
	Existing Conditions	Superelevation
Total	636.38	635.26
Fatal and Injury (FI)	283.40	282.71
Property Damage Only (PDO)	352.98	352.55
Reduction in Total Crashes over Existing Conditions	-	1.12

The effect of bringing existing superelevation rates into compliance with the AASHTO minimum values reduced the total number of expected crashes by 1.12 crashes over the 20-year analysis period. This reduction corresponds to a rounded CMF of 1.00 (0.2% reduction).

Benefit-Cost Ratio

Crash Severity Proportions

In order to perform a benefit-cost ratio Analysis in accordance with the procedures contained in the *Arizona Highway Safety Improvement Program Manual*, 2010, it was required that the total expected crash frequency be broken into five severity levels:

- Fatal
- Incapacitating injury
- Non-incapacitating injury
- Possible injury
- Property damage only (PDO)

Table 10-3 in the HSM provides default proportions for crash severity. The HSM values are based on State of Washington data (2002-2006). The project being located within the Navajo Nation, it was believed that it would be more appropriate to develop proportions based on data from this region. In order to calculate the necessary proportions, a data query of crashes on three rural two-lane, two-way state highways within the Navajo Nation and the Hopi Tribe in Arizona was performed. The segments queried were:

- SR 264 from US 160 to the State Border (approximately 150 roadway miles)
- US 160 from US 89 to the State Border (approximately 160 roadway miles)
- US 191 from I-40 to US 160 (approximately 130 roadway miles)

Five years of crash data were used (2007-2011). The total number of crashes for each severity level were determined and the percentages of the total were calculated. Table 9 illustrates the crash severity percentages used in the analysis.

Table 9: Navajo and Hopi State Highway System Rural Two-Lane Two-way Roadway Segment Crashes (2007-2011)

Severity Level	Percent of Total
Fatal	*12.4%*
Incapacitating Injury	*4.9%*
Non-Incapacitating Injury	*13.0%*
Possible Injury	*23.2%*
Property Damage Only (PDO)	*46.5%*

It should be noted that the percent of fatal crashes in this tribal region is significantly higher and the percent of property damage only crashes is much lower than the data presented in the Highway Safety Manual for rural two-lane, two-way roadways. The contributing factors resulting in this significant difference is unknown at this time. Likewise, it is unknown if these proportions may be applicable to all two-lane, two-way roadways in Arizona. The above proportions should not be used for other regions of Arizona without querying crash data from the specific region under study.

These percentages were then multiplied by the total expected crash frequencies derived from the Predictive Method results summarized earlier in this report. Annual averages were calculated by evenly distributing the total crashes over the 20-year analysis period.

8-foot Shoulders versus 5-foot Shoulders

A benefit-cost ratio analysis was performed in order to select the alternative that is expected to provide the most safety benefit with respect to cost. The estimates for each alternative included pavement, pipe extensions, and earthwork as the three major items quantified for cost. These cost estimates resulted in a total project cost of approximately $26.3 million for 8-foot shoulders and $16.5 million for 5-foot shoulders. For the sole purpose of comparing alternatives, an annual maintenance cost of $0 was assumed for each alternative. Tables 10 and 11 display the calculations of the benefit-cost ratios for the 8-foot shoulder and 5-foot shoulder, respectively.

Table 10: Benefit-Cost Ratio Tabulation for 8-foot Shoulder

Severity	Benefits				
	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	21%	0.83	$5,800,000	$4,806,228
Incapacitating Injury	1.56	21%	0.33	$400,000	$130,956
Non Incapacitating Injury	4.14	21%	0.87	$80,000	$69,485
Possible Injury	7.38	21%	1.55	$42,000	$65,109
No Injury	14.80	21%	3.11	$4,000	$12,429
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$5,084,207

Costs	Annual Costs
Total Construction Costs	$26,300,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$2,678,713
Annual Maintenance Cost	0
Total Annual Costs	$2,678,713

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$5,084,207	$2,678,713	1.90

CRF = Crash Reduction Factor

Table 11: Benefit-Cost Ratio Tabulation for 5-foot Shoulder

Severity	Annual Benefit Tabulation				
	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	16%	0.63	$5,800,000	$3,661,888
Incapacitating Injury	1.56	16%	0.25	$400,000	$99,776
Non Incapacitating Injury	4.14	16%	0.66	$80,000	$52,941
Possible Injury	7.38	16%	1.18	$42,000	$49,607
No Injury	14.80	16%	2.37	$4,000	$9,469
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$3,873,681

Costs	Annual Costs
Total Construction Costs	$16,500,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$1,680,561
Annual Maintenance Cost	0
Total Annual Costs	$1,680,561

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$3,873,681	$1,680,561	2.30

It is important to note that both alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would be to widen the shoulder to 8 feet since it would lead to the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. As an example, Table 12 includes the theoretical safety benefit of 5-foot shoulders versus 8-foot shoulders with a set annual budget of $10,000,000 to spend on shoulder widening on roadways with similar conditions. This summary is an oversimplification since the construction cost and benefit are unique to each roadway segment, however this example shows that applying the 5-foot shoulder systemically with an annual budget of $10 million would result in an increase in over 54 miles of shoulder widening and an over $4 million annual safety benefit.

Table 12: Theoretical Systemic Safety Benefit for $10 Million Annual Budget

	Annual Cost per Mile	Number of Miles	Annual Benefit per Mile	Total Benefit
Alternative A: 5-foot Shoulders	$68,455	146.1	$157,787	$23,049,928
Alternative B: 8-foot Shoulders	$109,113	91.7	$207,096	$18,980,036

Superelevation Improvements

A benefit-cost ratio analysis was performed to evaluate the benefit of bringing the existing superelevation into compliance with AASHTO criteria with respect to cost. A planning level cost estimate for bringing the superelevation into compliance was calculated on a per linear foot (LF) basis for two different improvement strategies including full curve reconstruction and differential overlay (See Appendix B). The unit costs for full reconstruction and differential overlay were calculated to be $143.61/LF and $67.08/LF, respectively. These unit costs were then multiplied by the total length of curvature for each curve to estimate the cost of superelevation improvements to each individual curve. For the purpose of this study, it was assumed that 1.9% was the maximum superelevation improvement that could be applied using differential overlay, which corresponds to a 6-inch overlay on the high side of the curve. Using this guideline, it was determined that each curve could be brought to within 1% of AASHTO compliance using only differential overlay. The benefit-cost ratio for each curve using differential overlay is summarized in Table 13.

Table 13: Benefit-Cost Ratio for Superelevation Improvements

	MP	% out of Compliance	CRF	Differential Overlay		
				Annual Benefit	Annual Cost	Benefit Cost Ratio
Curve 1	464.37	1.6%	1.7%	$ 1,119	$ 4,074	0.27
Curve 2	462.06	1.6%	1.4%	$ 373	$ 2,037	0.18
Curve 3	460.47	1.6%	1.6%	$ 773	$ 3,056	0.25
Curve 4	458.39	1.6%	1.2%	$ 1,570	$ 8,148	0.19
Curve 5	456.78	1.6%	1.1%	$ 5,189	$ 11,204	0.46
Curve 6*	454.55	-	0.0%	$ 0	$ 0	0.00
Curve 7	452.44	1.6%	1.2%	$ 5,491	$ 11,204	0.49
Curve 8	450.71	1.6%	1.3%	$ 7,448	$ 26,482	0.28
Curve 9	449.59	1.6%	1.3%	$ 3,407	$ 16,296	0.21
Curve 10	446.49	1.7%	1.1%	$ 1,937	$ 8,148	0.24
Curve 11	445.85	1.6%	0.9%	$ 740	$ 4,074	0.18
Curve 12	445.66	1.6%	0.5%	$ 356	$ 4,074	0.09
Curve 13	445.30	1.4%	0.9%	$ 394	$ 2,037	0.19
Curve 14	445.05	1.6%	0.7%	$ 375	$ 3,056	0.12
Curve 15	443.11	1.6%	1.2%	$ 2,730	$ 12,222	0.22
Curve 16	442.21	2.1%	1.8%	$ 5,690	$ 8,148	0.70
Curve 17	441.79	2.1%	2.0%	$ 4,215	$ 11,204	0.38
			Totals	**$ 41,807**	**$ 135,464**	**0.31**

*Curve 6 is a large radius flat curve

Prioritization of Segments

At the time of this report, the proposed widening improvements were split into two segments of approximately equal construction cost with the following limits:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

To prioritize the segments, the Predictive Method was applied assuming improvements to each segment were implemented independent of the other. The segment that had the greatest reduction in the expected number of crashes over the entire project limits would be considered for prioritization of construction timing. The segments were evaluated assuming 5-foot shoulders. The results of this analysis are shown in Table 14.

Table 14: Segment Prioritization Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes For Entire Project Limits	
	Segment I 5 foot Shoulders, Segment II Existing Conditions	Segment II 5 foot Shoulders, Segment I Existing Conditions
Total	593.09	574.87
Fatal and Injury (FI)	260.70	253.16
Property Damage Only (PDO)	332.39	321.71
Reduction in Total Crashes over Existing Conditions	43.29	61.51
Percent Reduction in Total Crashes over Existing	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for receiving priority in construction timing over Segment I based on estimated safety impact. Additional factors were considered in the prioritization decision, such as environmental impacts, right-of-way needs, construction phasing and coordination with other projects. Please note that further modifications in the segmentation were made by ADOT's Statewide Project Management Group based on a number of factors.

Results

Using the aforementioned resources and the HSM Predictive Method, the safety improvements of each alternative were quantified and compared to maintaining the existing conditions of the highway. The expected crash totals over the 20-year analysis period is summarized in Table 15.

Table 15: 2016-2036 Expected Total Number of Crashes

	2016 2036 Expected Total Number of Crashes			
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total	636.38	531.58	504.16	635.26
Reduction in Total Crashes over Existing Conditions	N/A	104.80	132.22	1.12
Percentage Reduction in Total Crashes over Existing Conditions	N/A	16.5%	20.8%	0.2%

Because of budgetary constraints, the proposed project was split into two separate segments to be constructed independently. As a result, each segment was evaluated for prioritization based on the potential reduction in the total number of crashes over the 20-year analysis period. Segment I included the west half of the project limits between MP 441.19 and MP 452.00. Segment II included the east half of the project limits between MP 452.00 and MP 465.74. Expected total crashes for the entire project limits were estimated for construction of Segment I first, with existing conditions remaining in Segment II. Similarly, expected total crashes for the entire project limits were estimated for construction of Segment II, with existing conditions remaining on Segment I. The results of this analysis are summarized in Table 16.

Table 16: 2016-2036 Expected Total Number of Crashes by Segment

	2016 2036 Expected Total Number of Crashes For Entire Project Limits		
	Existing Conditions	Segment I 5 foot Shoulders with Segment II Existing Conditions	Segment II 5 foot Shoulders with Segment I Existing Conditions
Total	636.38	593.09	574.87
Reduction in Total Crashes over Existing Conditions	N/A	43.29	61.51
Percentage Reduction in Total Crashes over Existing Conditions	N/A	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for construction prior to Segment I from a safety perspective.

However, additional factors were considered in the prioritization decision due to the small percentage difference (2.9%) in crash reduction between Segment I and Segment II.

The benefit-cost ratios in Table 17 were calculated using crash severity distributions for Navajo County two-lane two-way state highways in the ADOT Holbrook District and planning level cost estimates for each alternative.

Table 17: Safety Alternative Benefit-Cost Ratio

	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total Annual Benefit	$3,873,681	$5,084,207	$41,807
Total Annual Cost	$1,680,561	$2,678,713	$135,464
Benefit-Cost Ratio	2.30	1.90	0.31

The benefit-cost ratio for widening to 5-foot shoulders exceeded the benefit-cost ratio for widening to 8-foot shoulders. It is important to note that both shoulder widening alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would have been to widen the roadway to 8-foot shoulders since it would expect to result in the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. Based on this, ADOT decided to move forward with 5-foot shoulders for this project.

Due to additional budget constraints and coordination with adjacent projects, the project was divided into three segments of between six and nine miles each. The projects will be constructed with segments starting from the east. This is consistent with the prioritization of segment crash analysis summarized previously that showed Segment II on the eastern end having a larger crash reduction than Segment I on the western end.

The proposed superelevation improvements for all curves had a reduction of 1.2 crashes over the 20-year project timeframe and an overall benefit-cost ratio of 0.31. In addition, each curve was evaluated individually to determine if there was a benefit for superelevation improvements on a single curve. Due to the minimal crash reduction associated with superelevation, the largest benefit-cost ratio was 0.7 for curve 16 and therefore superelevation improvements are not recommended on any curves.

Strategies Employed

- HSM Part C – Predictive Method
- IHSDM Software

Publications Used/Produced Through this Effort

- Traffic Safety Evaluation, Using the Highway Safety Manual and the Interactive Highway Safety Design Model, SR 264 Burnside Junction to Summit, Kimley-Horn, 2012
- Transportation Research Board Annual Meeting – Poster Session, Application of HSM Predictive Method and IHSDM to Design Decision Making, ADOT and Kimley-Horn 01/2013

Lessons Learned

- The Predictive Method within Part C of the Highway Safety Manual defines a useful procedure to quantify the estimated safety impacts of project alternatives so that more cost-effective decisions can be made on reducing fatal and serious injury crashes.
- The Interactive Highway Safety Design Model was a straight forward software tool that guided us through the quantitative safety analysis consistent with the HSM.

Point of Contact

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- Mike Colety, Kimley-Horn (702-862-3609, Mike.Colety@Kimley-Horn.com)

References and Resources

- Highway Safety Manual (HSM). American Association of State Highway and Transportation Officials. Washington, DC. 2010. http://www.highwaysafetymanual.org/Pages/default.aspx
- Interactive Highway Safety Design Model (IHSDM). Federal Highway Administration. Washington, DC. http://www.ihsdm.org

Appendix E: FHWA Arizona Division Office INVEST OM Module Review

Sustainable Transportation Program

INVEST Operations & Maintenance

Operations and Maintenance (OM) is the third step in the lifecycle of a transportation project. This is where infrastructure planned, designed and constructed in prior steps is operated and maintained, resulting in needs for data collection and new project identification. This information is then passed back to the SP step, to complete the lifecycle of projects. This module focuses on performing system-level operations and maintenance activities in a manner that contributes to the overall sustainability of the highway network. The OM criteria are primarily written for the scoring of an agency's internal, system operations as well as, asset management and maintenance activities performed on the network infrastructure. The OM module contains 14 criteria and will constitutes the bulk of ADOT's 2015 sustainability efforts[9].

FHWA Arizona Division Office INVEST O&M Module Review

As a follow on to ADOT's 2015 INVEST Implementation Final Report, that highlighted the success of external stakeholder training, ADOT set out to develop a sustainability working relationship with the FHWA Arizona Division Office. It sparked new natures of discussion which may ultimately lead to all individuals involved learning more about various aspects of the development process. This type of learning opportunity is and will continue to be essential in ensuring project delivery in a consistent and timely manner. Further development of the scoring criteria and how those questions are sequenced in version 1.2 should further ensure the ultimate goal of implementing the program and allow for a more flexible applicability. The Division office provided a discussion based review of multiple layers of disciplines. This allowed for the individuals involved to view the breadth and depth of knowledge required by their peers to preform daily tasks.

The O&M module comprises 14 criteria and poses multiple questions for each. Through the process of discussing the INVEST modules with a particular focus on this OM effort ADOT was very fortunate to have the Arizona Division Office Project Delivery Team Lead take time to complete a questionnaire that condensed the OM module into a single set of questions. The purpose is to use INVEST to develop a common basis for understanding and advance sustainable transportation between ADOT and FHWA.

[9] https://www.sustainablehighways.org/917/about-the-operations-and-maintenance-module.html

Questionnaire

1. Name/Position:

Questions completed by Tom Deitering, Project Delivery Team Leader; Jen Brown, System Performance Team Leader; Kelly Larose, Safety Engineer; Toni Whitfield, Operations Engineer; Marissa Romero, Bridge Program Engineer; Rebecca Yedlin, Environmental Coordinator; Losa Wilson, Administrative Officer.

2. FHWA has a Sustainable Highways Initiative. Does your District have a role in implementing/interacting with the plan? [YES/NO]. **YES**

    i. IF YES, from the District perspective, do you have suggestions for improving the relevance or applicability of the plan to your work?

    ii. If NO, do you believe it would be beneficial for your District to implement/interact with plan to some degree? If so, please provide suggestions.

Comments:

FHWA provides technical guidance and support to implementing and interacting with the plan.

3. Does FHWA consider energy reduction and renewable energy usage in projects and plans? If so, does your District have a role in implementing/interacting with the plan? [YES/NO]. **Not at the Federal-aid Division Office Level since we do not develop projects and plans.**

    i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the plan to your work?

    ii. If NO, do you believe it would be beneficial for your District to implement/interact with plan to some degree? If so, please provide suggestions. It would be beneficial for the Division Office to be aware of ADOT's plan so we can offer support with implementing and interacting with the plan.

Comments:

Perhaps Federal Lands Highway Division would have this for the projects they develop?

4. Does FHWA have a fleet management plan with fossil fuel reduction goals. **YES** Does your District have a role in implementing/interacting with the plan? [YES/NO]. **YES**

    i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the plan to your work?

    ii. If NO, do you believe it would be beneficial for your District to implement/interact with the plan to some degree? If so, please provide suggestions.

Comments:
FHWA had petroleum reduction targets as outlined through executive orders 13423 and 13514. We met those reduction targets through a variety of initiatives including an emphasis on increased E85 consumption and replacing older vehicles with more fuel efficient models. A new executive order 13693

was issued in March 2015 that has shifted our specific focus for 2016 and beyond towards a reduction in greenhouse gas (GHG) emissions.

5. **Does FHWA have a plan that sets goals for post construction O&M material reuse and recycling. Does your District have a role in implementing/interacting with the plan? [YES/NO].** **YES**

   i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the plan to your work?

FHWA has established agency goals for enhancing the human and natural environment, increasing mobility, raising productivity, improving safety throughout the highway industry, and preserving national security. All of these goals are stated in our strategic plan, and we will ensure that the FHWA recycling policy and recycling programs are in alignment with those goals and underlying principles. This recycling policy statement is offered to advance the use of recycled materials in highway applications. It is intended to provide leadership, direction, and technical guidance to the transportation community for the use of recycling technology and materials in the highway environment.

   ii. If NO, do you believe it would be beneficial for your District to implement/interact with plan to some degree? If so, please provide suggestions.

Comments:

The FHWA policy is:

1. **Recycling and reuse can offer engineering, economic and environmental benefits.**
2. **Recycled materials should get first consideration in materials selection.**
3. **Determination of the use of recycled materials should include an initial review of engineering and environmental suitability.**
4. **An assessment of economic benefits should follow in the selection process.**
5. **Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.**

6. **Does FHWA have a safety management program.** **YES** **Does your District have a role in implementing/interacting with the program? [YES/NO].** **YES**

   I. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the program to your work?

We are already actively involved in implementing the program and interacting with partners making it very relevant and applicable to our work.

   II. If NO, do you believe it would be beneficial for your District to implement/interact with program to some degree? If so, please provide suggestions.

Comments:

7. **Does FHWA have an environmental commitments tracking processes and practices improvement goal?** **NO** **Does your District use these processes and practices? [YES/NO].** **NO**

   1. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the processes and practices to your work?

2. If NO, do you believe it would be beneficial for your District to use the processes and practices to some degree? If so, please provide suggestions.

Comments:
ADOT is developing an environmental commitments tracking system, and the Arizona Division Office will have access to it once in place.

8. **ADOT has a pavement management system. Does your District use/interact with the system? [YES/NO].** **NO**

   i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the system to your work?

   ii. If NO, do you believe it would be beneficial for your District to use/interact with the system to some degree? If so, please provide suggestions.

It would be very helpful to be able to pull information together on the condition of segments of the highway system so that we understand where the priorities are and how the projects under development will address these.

Comments:

The Division Office does not have access to the PMS, but we would like to. We are looking forward to the rollout of Arizona Transportation Asset Management System (AZ-TAMS) the intuitive online tool for viewing and analyzing information on all aspects of the transportation system. We understand it will provide the means to "develop a comprehensive performance mechanism to evaluate the overall transportation health" and will be capable of producing system performance measure reports that meet MAP-21 requirements. We would encourage ADOT to incorporate mechanisms for external partners to access this information.

9. **ADOT has a bridge management system. Does your District use/interact with the system? [YES/NO].** **Yes**

   i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the system to your work?

The division bridge engineer uses the system to look up bridge inspection, inventory, and condition history. ADOT uses AASHTO BrM software for their bridge management system and they just updated their version to the 64 Bit BrM (pontissql2). It would be helpful if BrM had a module that could assist taking the bridge element level data and optimize (systematically) preventive maintenance projects for bridges in Arizona (i.e. bridge deck seals, joint replacements etc.). This would be helpful because ADOT is in the process of developing a bridge systematic preventive maintenance program.

   ii. If NO, do you believe it would be beneficial for your District to use/interact with the system to some degree? If so, please provide suggestions.

Comments:

10. **ADOT has a maintenance management system. Does your District use/interact with the system? [YES/NO].** **NO**

i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the system to your work?

ii. If NO, do you believe it would be beneficial for your District to use/interact with the system to some degree? If so, please provide suggestions.

FHWA does not participate in maintenance, but we do monitor if the state is meeting the agreement to maintain facilities as constructed with Federal-aid funds. However, some of the inventory items could be used to feed a future asset management system. FHWA can participate in preventive maintenance, where eligible preventive maintenance activities extend the service life of a roadway asset or facility in a cost-effective manner.

Comments:

11. **ADOT has elements of a traffic control infrastructure and maintenance system. Does your District use/interact with these elements? [YES/NO].** **NO**

    i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the system to your work?

    ii. If NO, do you believe it would be beneficial for your District to use/interact with the system to some degree? If so, please provide suggestions.

Information on the infrastructure and maintenance system could be beneficial for a future asset management system.

Comments:

12. **ADOT has a road weather management program. Does your District use/interact with the program? [YES/NO].** **NO**

    I. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the program to your work?

    II. If NO, do you believe it would be beneficial for your District to use/interact with the program to some degree? If so, please provide suggestions.

Information on how to access this program and its purpose would be beneficial. This could potentially be used for emergency reporting that FHWA-AZ does to FHWA-HQ.

Comments:

i. ADOT uses ITS technologies. Does your District use/interact with ITS? [YES/NO]. **YES**

    i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of ITS to your work?

The Division uses/interacts with ITS elements that provide traveler information and incident information, such as HCRS, AZ511, and emails from TOC operators when triggered by specific reporting requirements (i.e., closure duration, national interest, no. of fatalities, etc.). These are used for emergency reporting purposes, as well as monitoring incident details for areas/locations that need additional attention and

collaboration with partners. Receiving these emergency reporting incidents from TOC operators in a more automated and consistent fashion would be beneficial for expedited reporting and to ensure no missed reportable incidents.

ii. If NO, do you believe it would be beneficial for your District to use/interact with ITS to some degree? If so, please provide suggestions.

Comments:

Additionally, the Division's Administrative Assistant receives individual incident emails that could be provided in a manner for sorting and filtering in a database. This would be beneficial as the current process requires extra work in organizing and distributing the information to the Division staff and the information is not used to its full potential by the staff because of the current manner in which it is presented.

13. **ADOT has a work zone traffic control program. Does your District use/interact with the program? [YES/NO].** NO

    i. IF YES, from the District's perspective, do you have suggestions for improving the relevance or applicability of the program to your work?

    ii. If NO, do you believe it would be beneficial for your District to use/interact with the program to some degree? If so, please provide suggestions.

Division representative is unaware of this program. More information needed to educate the Division on this program, its purpose, and its capabilities to determine whether it is beneficial for our use/interaction.

Comments:

End

Appendix F: Agency Sustainability Plan Drafts

MEMORANDUM

TO: Assistant Director, Administrative Services Division

FROM: The ADOT Sustainable Transportation Program – Environmental Planning

CC: State Engineer's Office and Environmental Planning - Group Manager

DATE: 03/31/2016

RE: Draft Consolidated Energy Efficiency and Use Plan

The Arizona Department of Transportation (ADOT) Sustainable Transportation Program is requesting the development and/or review of an agency wide consolidated energy efficiency and use plan through ADOT's Administrative Services Division (ASD). The initiation of such a plan would take place as follow: introduction through this memorandum, the development of a subsequent action plan with measurable data entry points, implementation of such a plan, and finally concluding in a new ADOT policy for an annual renewal and evaluation.

The goal will be to minimize the agencies energy use through applied new technologies and/or policies for facilities, training of internal staff, as well as, advantageously evaluating best management practice through construction and maintenance activities. This would ultimately result in reduced energy use relative to building consumption and limiting resource use in the field.

This will aid in ADOT's ability to ensure the effect use of resources in order to obtain optimal results. Strategic investment in resources and their use will lead to a more economically secure program and development process. Maintaining peak health and performance of infrastructure is critical to Arizona's economic vitality, quality of life and natural and built environments. Through continual improvement, evaluation and evolution of our process and programs, our agency will continue to expand in a socially responsible and financially accountable manner.

ADOT shall make decisions and proceed with actions such as, but not limited to, the following to secure an effectively balanced energy use plan:

- Support the reduction in vehicle miles traveled
- Consider energy reduction through the use of modernized lighting fixtures (including both facility and infrastructure use)
- Develop an internal training and recognition program for department energy use reduction efforts
- On projects of particular community interest list expected construction equipment use and perform qualitative evaluations of embodied/lifecycle emissions and energy use of select equipment as part of the design/alternatives consideration process

Draft Consolidated Energy Efficiency and Use Plan continued

- Consider location of existing fuel resources and potential effects on local energy production (when in rural or remote areas)
- Support existing policies such as “no idling” in the field through outreach and information distribution

MEMORANDUM

TO: Assistant Director, Administrative Services Division

FROM: The ADOT Sustainable Transportation Program – Environmental Planning

CC: State Engineer's Office and Environmental Planning - Group Manager

DATE: 03/31/2016

RE: Draft Consolidated Reduce, Reuse and Recycling Plan

The Arizona Department of Transportation (ADOT) Sustainable Transportation Program is requesting the development of an agency wide consolidated reduce, reuse and recycling plan through ADOT's Administrative Services Division (ASD). The initiation of such a plan would take place as follow: introduction through this memorandum, the development of a subsequent action plan with measurable data entry points, implementation of such a plan, and finally concluding in a new ADOT policy for an annual renewal and evaluation.

According to the Federal Highway Administration, Recycled Materials Policy issued 09/08/2015:

1. Recycling and reuse can offer engineering, economic and environmental benefits.
2. Recycled materials should get first consideration in materials selection.
3. Determination of the use of recycled materials should include an initial review of engineering and environmental suitability.
4. An assessment of economic benefits should follow in the selection process.
5. Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.

The goal will be to minimize the agencies use of new raw materials through the reuse and recycling of existing viable materials on site or throughout the state when applicable during construction. Through applied new technologies and/or policies, training of contractors and technical staff, as well as, advantageously evaluating best management practice through construction and maintenance activities, the agency may more effectively evaluate the particular project characteristics to better apply reuse and recycle opportunities. This would ultimately result in reduced new material use relative to the construction process aiding in managing a fiscally responsible agency, reduce finite resource material use and promote more sustainable/SMART/Complete transportation practices.

This will aid in ADOT's ability to ensure the more effect use of resources in order to obtain optimal results. Strategic investment in resources and their use will lead to a more economically secure program and development process. Maintaining peak health and performance of infrastructure is critical to Arizona's

economic vitality, quality of life and natural and built environments. Through continual improvement, evaluation and evolution of our process and programs, our agency will continue to expand in a socially responsible and financially accountable manner.

ADOT shall make decisions and proceed with actions such as, but not limited to, the following to develop a reasonable reduce, reuse and recycle plan:

- The Agency should consider emphasizing the use of recycling technologies when applicable to a given project area
- Development of internal and external training opportunities to inform key technical staff of new and developing recycled material uses, implementation of best management practices for material reduction and design guidance for reuse
- On projects of particular community interest, evaluate the possible reduction, reuse and recycling of materials through interagency outreach and stakeholder involvement
- Consider material end-of-lifecycle uses, timeframe and decomposition
- Develop considerations for outside agency coordination such as excess milling sharing policies in rural or remote areas

The agency may evaluate the need or application of above through more comprehensive cost benefit analysis of both project specific opportunities and fiscal year quarterly evaluations.

MEMORANDUM

TO: Assistant Director, Administrative Services Division

FROM: The ADOT Sustainable Transportation Program – Environmental Planning

CC: State Engineer's Office and Environmental Planning - Group Manager

DATE: 03/31/2016

RE: Draft Consolidated Internal Sustainability Plan

The Arizona Department of Transportation (ADOT) Sustainable Transportation Program is requesting an agency consolidated internal sustainability plan, further referred to as the Plan, to be developed through ADOT's Administrative Services Division (ASD). The subsequent process to develop the Plan is envisioned as the Plan initiation (this memorandum), a subsequent action plan to be implemented, and ultimately leading to a new ADOT Policy for an annual renewal of evaluation.

The three primary principles of sustainability revolve around achieving an efficient, well-balanced use of economic, social, and environmental resources commonly known as the triple bottom line.

Maintaining optimum health and performance of infrastructure is critical to Arizona's economic vitality, quality of life, and natural and built environments. ADOT recognizes the critical need to plan and prioritize resources more efficiently in order to maintain and operate a robust, economically beneficial transportation network. Through continuous improvement practices, ADOT strives to strategically invest resources to achieve the highest possible return. ADOT also recognizes, in relation to investment and return dynamics, the importance of delivering transportation solutions in a more sustainable manner to achieve economic, social, and environmental goals.

Initial Draft - Internal Sustainability Plan, in order to enact an agency-wide sustainability policy

ADOT shall make decisions and proceed with actions that promote conservation and focus on the balance of economic, environmental, and social needs which focus on the following:

- Support reduction in vehicle miles traveled
- Facilitate the development of a consolidated energy use and efficiency plan
- Facilitate the development of a consolidated recycling plan
- Facilitate the development of an employee alternative fuel vehicles commuting plan
- Encourage cost-effective sustainable practices for construction and operations, which may include standard specification evaluation and improvement
- Promote activities to ADOT stakeholders and maintain a leadership role in sustainable transportation systems
- Ensure above actions support ADOT Strategic Focus Areas, Lean Initiatives, Long Term Planning, and Practical Design

Appendix G: Roles & Responsibilities

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REFERENCES - PART II

[i] FHWA INVEST. https://www.sustainablehighways.org/100/about.html. Accessed December 10, 2015.

[ii] FHWA INVEST https://www.sustainablehighways.org/1811/version-12.html. Accessed December 29, 2015.

[iii] FHWA INVEST Matrix. https://www.sustainablehighways.org/files/3316.pdf. Accessed December 29, 2015.

FIGURES – PART II