7 Technology Considerations

This chapter describes the recommended ITS and operations environment for the Spine corridor network, including freeways and arterial streets. In an age defined by rapidly evolving technology and innovations, ITS technologies are critical components of transportation networks throughout the world, supporting safety and mobility. Technology and operations strategies can provide cost-effective solutions to mobility challenges, enable real-time data sharing among key system operations partners and connect travelers to decision-making information about current road and travel conditions.

MAG and its partner agencies continue to explore how technology can be used to support advanced operations strategies. The recommendations in this document were developed using the needs assessment and the corridor's identified operational gaps, but they were also largely informed by best practices and anticipated technology innovations for operations from around the world.

7.1 Background and Document Purpose

Agencies in the MAG region are advancing ICM concepts, which emphasize active corridor operations to coordinate between freeways and parallel arterials. New technologies are being piloted to test advanced ramp metering capabilities and detection systems that identify wrong-way drivers. Several local agencies are testing and operating adaptive traffic control systems, which allow traffic signals to respond to current traffic conditions rather than being set to fixed time-of-day signal plans. MAG and its member agencies are looking at successful implementations of active management strategies around the world to identify cutting-edge strategies that could be implemented on corridors such as the Spine to address specific safety and mobility issues.

This section discusses how technology will influence the transportation network through the 2040 horizon, identifies key opportunities to integrate new technologies into Spine corridor operations and recommends infrastructure enhancements. This section also provides planning-level cost opinions for technology improvements.

7.1.1 Technology Influences

The transportation system as users know it today will look very different in 2040. In the MAG region, numerous technology developers are already testing automated cars on the road network, and recently have begun recruiting real-world "civilian" drivers to see how these vehicles perform for typical day-to-day driving needs.

Transportation, like many things, is becoming more "on-demand"—and this will continue to drive innovation in personal mobility choices. Today's websites will continue to yield to more mobile applications that will either bring transportation to travelers or inform travelers of changes they should make to their travel plans. Vehicles will be able to make trip adjustments based on real-time information regarding current and predicted road conditions. Travelers will expect predictions of what travel conditions will be like and information about their trip and travel options.

Technology innovations will introduce new partners into the mobility supply chain. This is a fast-moving and competitive marketplace, with several layers of potential partners to collect, aggregate, share, analyze and archive information. Developers are needed to create technology platforms to process information and provide it in a usable format. Partnerships need to be in place to enable secure data exchanges. Information that agencies could not easily obtain will become ubiquitous and potentially sequestered in proprietary private-sector systems. For key partnerships to be effective, an increased focus on acquiring and sharing data will be needed.

The Spine corridor contains some of the initial phases of ADOT's FMS, in operation since 1995 and expanded and upgraded over time to replace older technology with newer, more efficient systems. Along with these upgrades, ADOT also has advanced its operations capabilities, using the deployed systems to collect and disseminate travel time information, automate notifications to agencies about impacts on the network and share access to systems (such as camera images). Local agencies also have been steadily implementing and upgrading their traffic management capabilities, including traffic signal connectivity, communications infrastructure, real-time monitoring, freeway/arterial coordination planning and local TOCs. A strong foundation exists for expanding agencies' use of technology to improve safety and mobility throughout the Spine corridor.

7.1.2 Current Technologies and Initiatives in the Spine Corridor

The Spine NAR included details of current systems, technologies and initiatives in the Spine corridor, which are summarized in the following subsections. These existing capabilities provide an important foundation for future enhanced technology applications. This section concludes with recommendations for future technology infrastructure in the Spine corridor.

7.2 Freeway Operations and Assets in the Spine Corridor

7.2.1 ADOT Transportation System Management and Operations

ADOT was among the lead states to formalize TSMO at the agency. TSMO refers to a suite of systems, processes, collaboration and commitment to improving reliability and safety of the transportation network. It leverages available capacity by enhancing operations and coordination, particularly when nonrecurring events affect the transportation system, such as traffic incidents, work zones, hazardous weather or major planned special events. To better respond to these events and proactively address congestion and safety issues, ADOT's TSMO Division brought together key groups responsible for traffic operations, safety, system management and maintenance (traffic and systems). A benefit of ADOT's reorganization to establish the TSMO Division is the ability to coordinate important functions across these groups, such as traffic incident management, safety, system maintenance and system operations, performance management and system planning.

7.2.2 Freeway Management System

ADOT's FMS on I-10 and I-17 is centrally controlled from ADOT's TOC, which is staffed 24 hours per day, 7 days per week, 365 days per year. The FMS includes CCTV cameras, vehicle sensors, DMS and ramp meters for monitoring and mitigating traffic congestion on Phoenix-area freeways. Communication with the FMS field devices is provided through ADOT's extensive fiber-optic communication network that runs parallel to major freeways.

7.2.4 ADOT Traffic Operations Center

ADOT's TOC provides central management of the statewide transportation network. At the TOC, operators monitor and manage the Phoenix-area FMS. The ADOT TOC monitors and responds to both recurring and nonrecurring congestion on state road facilities. In addition to operators, a public information officer (PIO) and a DPS trooper are based at the ADOT TOC, providing liaison support for their respective departments during incidents.

Operators at the ADOT TOC monitor traffic conditions.

7.2.5 Traveler Information

Traveler information has been a core component of ADOT's FMS since it was constructed. Several activities and systems provide travelers, partner agencies and the media with current information about road and travel conditions:

- ADOT's PIO/Communications staff at the TOC actively disseminate information and notifications using tools such as Twitter (@ArizonaDOT), which currently has over 173,000 followers.
- ADOT has a long-standing relationship with local media channels to share camera images, alerts and travel times for traffic reports and updates.
- The ADOT 511 phone system provides corridor-based travel conditions information, including alerts for high-priority or emergency road closures or conditions. The www.az511.gov website includes an interactive map that can zoom in on urban areas to provide camera views, speed maps and current and planned closures and restrictions
- ADOT displays travel time estimates on freeways throughout Phoenix and Tucson using data gathered from FMS detectors.
- Two key data management systems support ADOT's traveler information capabilities. The Highway Condition Reporting System (HCRS) tracks incidents, closures, planned construction and planned event advisories. The HCRS is an important data source for 511 and www.az511.gov. The Regional Archived Data System (RADS) coordinates with HCRS and allows for data sharing and travel time calculation, and can support performance monitoring.

7.2.5.1 Active Traffic Management for Interstate 17

ATM strategies were evaluated for the I-17 corridor between I-10 and SR-101L and a concept of operations was developed for a host of ATM strategies. The concept included adaptive ramp metering, lane control signs on overhead gantries to support lane control and variable speed limits, queue warning through advance detection algorithms and arterial infrastructure to support freeway detours onto arterials during freeway lane closures. ADOT decided not to move forward with deploying this concept because of cost and maintenance concerns and because it wanted to explore other solutions that could address specific mobility and safety issues on the I-17 corridor. ADOT is now considering an "ATM lite" concept, where selected ATM strategies, such as smart ramp metering, are considered for different portions of the freeway based on their specific challenges.

7.2.5.2 Interstate 17 Wrong-Way Detection Deployment Pilot Project

Wrong-way driving has been a systemic issue in Arizona, causing incidents and fatalities that may be able to be avoided. DPS receives an average of 25 calls per month reporting a wrong-way driver. In response to the wrong-way driving problem in Arizona, ADOT is implementing a wrong-way driving detection pilot project along I-17 from I-10 to SR-101L. The project will provide thermal cameras at freeway exit ramps able to detect a wrong-way driver and to alert DPS and the ADOT TOC automatically. High-definition cameras will be mounted in the gore area of exit ramps to capture images of the vehicle as it enters the freeway. Thermal cameras along the I-17 main line will be able to track the wrong-way driving vehicle as it moves along the freeway. The project will be installed and tested in 2017, and is expected to be fully operational by early 2018. This pilot project will be closely monitored for effectiveness and potential deployment along other urban freeway corridors in Arizona.

A freeway message sign warns travelers of a wrong-way driver.

7.2.5.3 Integrated Corridor Management Planning for Interstate 10

The goal of ICM is to leverage available capacity across multiple modes (e.g., freeway, arterial, transit) to balance recurring congestion and to improve operations during freeway incidents or closures. The I-10 corridor has been a key focus for the region for initial ICM planning, and some level of expanded ICM implementation is envisioned to be a priority near-term strategy emerging from the Spine study. Early project concepts for the I-10 corridor have focused primarily on incident-based congestion—that is, when a major freeway incident closes or significantly restricts traffic mobility on I-10. It considers how state and local partners safely and effectively manage diverting traffic onto the adjacent arterial network. MAG received a grant from the U.S. Department of Transportation to develop an ICM plan and requirements for the I-10 corridor.

7.2.6 Connected Vehicle Pilot Program on Interstate 17

ADOT is working on a project to deploy dedicated short-range communication (DSRC) radios along the I-17 corridor near Anthem and New River. This pilot project expands, and will connect to, the SMART*Drive* connected vehicle pilot in Anthem (led by MCDOT). The goal of connected vehicles is to provide real-time communication between equipped vehicles and roadside infrastructure, providing transportation agencies with an ubiquitous data source and with enhanced decision-making information for system operations strategies. The radios will be deployed on freeway DMS signs and CCTV camera poles. This deployment of DSRC radios along the corridor will connect to the testbed on Daisy Mountain Drive to create an extended testbed within a freeway corridor. Radios are expected to be installed later in 2017. Connected vehicle infrastructure should be considered for the entire Spine corridor to allow for extensive connected vehicle operations and testing and to keep the region at the forefront of connected vehicle readiness.

7.3 Arterial Operations and Assets in the Spine Corridor

Arterial street management agencies are also investing in arterial monitoring and management infrastructure. Phoenix, Tempe and Chandler are continuing to expand their arterial traffic monitoring and management capabilities to improve responsiveness to conditions on key arterials in real time.

7.3.1 City of Phoenix

The Phoenix Traffic Management Center (TMC) is located at Phoenix City Hall and oversees approximately 1,200 traffic signals, 24 miles of light rail transit intersections, more than 100 CCTV cameras, 5 arterial DMS, more than 72 miles of fiber-optic backbone, more than 900 wireless radios and several miles of twisted-pair copper cable. The City of Phoenix TMC operates during business hours, Monday through Friday.

An intergovernmental agreement (IGA) is being developed between the City of Phoenix and ADOT to allow ADOT to control the City of Phoenix signal system after business hours from the ADOT TOC. This after-hours support will allow ADOT to implement preset signal timing plans at intersections along I-10 if an incident or event on the freeway occurs that will affect Phoenix arterials. This agreement could be extended to the Spine corridor for after-hours support for arterial detours prompted by freeway closures.

Additional programmed projects in Phoenix through 2017 include:

- Creating predefined signal strategies and timing plans based on the developed concept of operations.
- Adding cameras and DMS throughout Phoenix and focusing investments on the Downtown Traffic Management System for special event management.
- Extending fiber-optic backbone to cover more signal and ITS infrastructure throughout Phoenix.

7.3.2 City of Tempe

Tempe's transportation system includes the arterial street system, bus network, bicycle trails and Valley Metro light rail transit. Tempe is an event "hotspot" in the region, hosting more than 150 special events each year. These events require road closures and support from police officers, fire department personnel and others to manage transportation to and around the event.

The Tempe TMC operates Monday through Friday during business hours. There are 222 traffic signals on arterial and collector routes, and Tempe has an IGA with ADOT to own, operate and maintain traffic signals at freeway traffic interchanges. CCTV cameras are located at arterial crossings and along the Valley Metro light rail transit in Tempe.

Programmed projects through 2017 include fiber communications along Elliot and Rural roads and DMS at key locations throughout. CCTV infrastructure is programmed for implementation in the next 4 years as part of projects programmed in the MAG TIP.

7.3.3 City of Chandler

The City of Chandler's current infrastructure includes a TMC, a fiber communication network on nearly all arterial streets throughout the city that connects 216 traffic signals, three DMS and more than 800 video devices (consisting of pan-tilt-zoom CCTV and video image detectors) to the TMC. Chandler's TMC operates weekdays during business hours.

Chandler was the first local agency in the region to deploy Bluetooth readers to estimate arterial travel times and post them on arterial DMS alongside freeway travel times. These real-time travel times are posted on DMS on three major arterial roads in Chandler from 6 a.m. to 7 p.m. Monday through Saturday. These signs also provide traveler information in response to major incidents or road closures.

Programmed projects in Chandler through 2017 include additional CCTV and fiber communications.

7.3.4 Maricopa County

The MCDOT TMC is open Monday through Friday, and will extend operations hours if a large-scale incident after business hours requires support from MCDOT's Regional Emergency Action Coordination Team (REACT). The MCDOT TMC serves in an important coordinating role for arterial incidents and issues social media alerts and notifications about incidents or events affecting the network.

Operators at the MCDOT TMC monitor traffic conditions.

MCDOT owns and operates RADS, which collects all ADOT FMS data, many local agency data sets and Phoenix Fire Department filtered computer-aided dispatch (CAD) data. The RADS stores and processes the data for a variety of purposes, such as calculating freeway travel times to be posted on freeway DMS. The system is linked with HCRS to provide real-time traffic data to support speed maps on the ADOT 511 website. It also provides supplemental road condition information collected from public safety agencies and local agencies that is not already collected through the HCRS system.

Future enhancements to RADS processes include:

- TMC center-to-center interfaces with other cities.
- Transit information integration into RADS system.
- Support of "connected vehicle" development activities.
- Retrieval of DMS display data for archiving.

7.3.4.4 Bell Road Adaptive Signal Timing Project

Agencies in the region are beginning to test adaptive signal capabilities, and Bell Road is the first regionally significant corridor where adaptive traffic signal control is being implemented. Multiple segments of Bell Road are testing different adaptive traffic signal control strategies, and the City of Phoenix's segment crosses I-17. Adaptive signal operations are being implemented along this corridor to adaptively respond to changing traffic conditions, particularly at freeway intersection locations, and to demonstrate multijurisdictional coordination of adaptive systems. This project is being led by MCDOT and includes the Cities of Surprise, Phoenix, Peoria, Glendale and Scottsdale.

7.4 Coordinated Traffic Incident Management

According to the U.S. Department of Transportation, an estimated 50 percent of congestion is caused by traffic incidents. Arizona agencies are actively coordinating to improve response, clearance and management of incidents affecting freeways and arterials in the following ways:

- DPS operates a 24-hour-per-day, 7-day-per-week, 365-day-per-year dispatch center for statewide incident and emergency response. Incident information is logged and subsequently disseminated to DPS vehicles through a CAD system, and a CAD data feed is provided to the ADOT TOC and MCDOT TMC via a dedicated workstation. This data feed improves real-time notifications to these agencies.
- In 2015, through a partnership with DPS, ADOT and MAG, DPS stationed a uniformed officer at the ADOT TOC with a goal of improving incident response and communications. In the first year of the program, this co-location helped reduce the average time to clear freeway incidents by almost an hour.
- The regional Freeway Service Patrol (FSP) assists stranded motorists on Phoenix metropolitan area freeways and helps to eliminate road hazards and distractions. FSP helps with non-emergency responses, such as flat tires, fuel or calling a tow truck. DPS and MAG co-fund this program for the Phoenix metropolitan area at $1 million per year in the MAG TIP. AAA Arizona also provides some sponsorship and support for the program.
- The Arizona Local Emergency Response Team (ALERT) is operated by ADOT and is a 24-hour-per-day, 7-day-per-week response team for major crashes, emergencies or weather-related events along freeways in the Phoenix metropolitan area. In the event of an incident, law enforcement will determine whether assistance from the ALERT team is needed to support traffic control.
- The AZTech Traffic Incident Management Coalition, led by DPS, brings together state and local responders, law enforcement, fire, emergency medical services and tow operators for monthly strategic meetings regarding how to improve coordination and communication, provide training and track incident response performance.
- Each city within the Spine study area has its own police and fire department. The Phoenix Fire Department dispatches local fire and emergency medical dispatching services for approximately 23 jurisdictions in the Phoenix metropolitan area.

7.5 Other Technology and Operations Initiatives in the MAG Region

Although not directly part of the Spine corridor, technologies and initiatives discussed in this section highlight activities on other corridors in the region, or on a regional level, that can be evaluated for potential Spine implementation.

7.5.1 Adaptive Ramp Metering Pilot on State Route 51

Ramp meters are deployed on all freeway entrance ramps within the Spine corridor. Most are currently activated by time-of-day scheduling and have adjustable activation thresholds based on main line detection near the ramp. In the fall of 2016, ADOT began testing an algorithm for adaptive and responsive ramp metering on SR-51 where the ramp meter program automatically selects the best metering rate for the series of ramp meters along the corridor based on freeway congestion and queuing at the ramp meter.

Detectors along the entrance ramps assess whether ramp traffic is backing up and accordingly adjust the ramp metering timing based on a custom algorithm. At locations where ramp meter queues become extended, the metering rate is sped up, while another ramp meter with less queue is slowed down. ADOT is conducting a before-and-after evaluation of the ramp metering pilot to provide insights into the benefits and lessons learned.

7.5.2 SR-101L Integrated Corridor Management

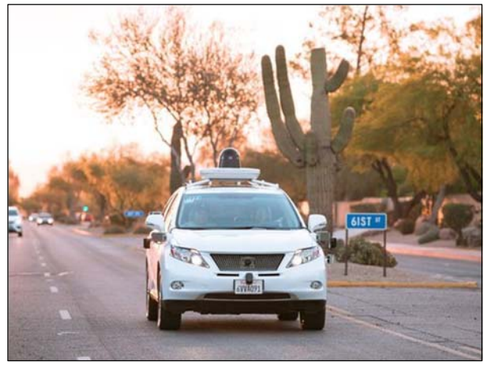
ADOT, Scottsdale, MCDOT, the Salt River Pima-Maricopa Indian Community and MAG jointly developed an ICM program for the SR-101L corridor in Scottsdale. The SR-101L ICM plan includes protocols for improved coordination and communication between operating and responding agencies involved when an arterial detour is needed through the city of Scottsdale to accommodate traffic from SR-101L. The plan includes notification processes and traffic management protocols that use a strategic combination of Scottsdale arterial signal and infrastructure control, ADOT freeway DMS messaging and traffic control to most efficiently detour traffic off and back on to the freeway. Key partners included transportation, law enforcement and emergency responders.

The plan has been implemented and has helped partner agencies better manage freeway incidents on SR-101L and implement construction detours related to the SR-101L widening/HOV lane project.

With the success of this first implementation along SR-101L in Scottsdale, plans are being developed to extend the ICM along SR-101L through Phoenix and the West Valley cities.

7.5.3 Autonomous Vehicle Testing

In 2015, the Arizona Governor signed an executive order to support autonomous vehicle testing and attract new technology business to the state. Companies are attracted to Arizona because of the unique experiences that the cars can be tested with, including extreme heat, watering trucks, dust storms and a variety of transit, bicycle and pedestrian facilities.



An autonomous vehicle is tested in Arizona.

Since 2015, Google (Waymo), Uber, General Motors, Ford and others are now testing autonomous vehicles throughout the Phoenix metropolitan area. These tests include human drivers who sit in the front seats to ensure the vehicles are operating properly. Google has reached out to the City of Chandler Transportation Department to learn about the information behind the traffic signal and ITS systems in the city and to identify ways that the autonomous vehicles could better interface with city traffic signals.

7.6 Key Needs and Gaps to be Addressed in the Spine Corridor

Considering the existing capabilities related to operations and management along the Spine corridor, this section identifies some of the key gaps that can be addressed using strategically deployed technology and systems.

7.6.1 Real-time Data

The FMS on freeways in the Spine corridor provide ADOT with condition data that can be used to monitor and make real-time decisions related to freeway operations. However, this level of data is not equally available for locally owned adjacent arterials in the corridor to support real-time monitoring of arterial operations.

To date, private-sector data have not been widely used to supplement arterial data, thus leaving a gap in the data available for real-time systems management and operations in the region. Crowdsourcing options use a combination of anonymous crowd-sourced data and historical data to identify speeds or provide travel times. Several acknowledge that their models are still being refined and that arterials pose some different challenges than freeway corridors. Connected vehicles, when deployed, can also serve as a valuable source of real-time information on the transportation network.

Recently, ADOT issued a request for proposals to obtain statewide data from a third-party provider(s). The advancement of this project would provide ADOT with probe data for the entire state, including arterials and freeways, which would create the opportunity for the region to pursue strategies that require or benefit from real-time data. These might include real-time traffic signal optimization strategies or supporting the implementation of freeway-arterial detours throughout the region.

7.6.2 Integrated Operations Between Freeways, Arterials and Transit

While freeways, arterials and transit are each operated by different agencies, operations along the corridor should be coordinated and complementary to provide the greatest efficiency for travelers along the corridor. Integrating the operations of these facilities should mean that operators from the different agencies are in frequent communication and that data and real-time condition information from each facility/agency are shared. This will facilitate better use of existing corridor capacity and provide better and more consistent information to the traveling public.

7.6.3 Decision Support Systems

Going one step beyond integrated operations, regional agencies have discussed developing a Decision Support System (DSS) to manage the regional transportation network, including the Spine corridor. A DSS leverages real-time data and the operational capabilities of agencies' existing central management systems, concurrently with a set of preset response plans, to make operations recommendations for managing the transportation network in response to existing conditions. A DSS uses a software algorithm to examine the transportation network as a whole, including freeways, arterials and transit, and to identify the best operational responses for current network conditions.

7.6.4 Improved Intersection Safety for All Modes

Many of the freeway interchanges along the corridor need enhancements to improve the safety of bicyclists and pedestrians. Freeway interchanges can have specific safety challenges for bicycles and pedestrians because cars approach the intersections at high speeds and because a multi-intersection configuration is needed to support on- and off-ramps for both directions. Intersection geometry improvements are being addressed as part of the Spine corridor recommendations, but the role of technology in improving intersection safety for bicycles and pedestrians should be considered—at freeway interchanges and at regular arterial intersections within the Spine corridor. Technologies will likely include both intersection-based technologies that can be influenced by public agencies, such as detection and connected vehicle infrastructure, and vehicle-based technologies that will be private-sector driven, such as collision avoidance systems built into vehicles.

7.6.5 Enhanced Local Operational Capabilities

Gaps in infrastructure, staff and systems can hinder a local agency's ability to most effectively monitor, operate and manage its network. For example, many infrastructure gaps, such as lack of detection or CCTV cameras, occur along arterials within the Spine corridor in Phoenix that limit Phoenix's ability to manage traffic on the arterials because it cannot gather real-time data about the intersection or traffic flow. All local agencies within the Spine corridor have challenges related to staffing at local TMCs or operations facilities to actively monitor and manage traffic conditions.

7.7 Operational and Technology Approaches for Spine Corridor

This section describes near- and long-term concepts for operational enhancements to freeways and arterials in the Spine corridor. The concepts include technologies and processes that support advanced operations and management of the corridor.

7.7.1 Enhanced Freeway and Arterial Management Concept

The Enhanced Management approach involves technology and operational strategies to support advanced traffic management on freeways and arterials and improved freeway-arterial coordination. Technologies have specifically been chosen as part of this concept to support multiple uses; for example, freeway and arterial signs could provide traveler information for commuters, queue or travel time information for freight destinations or mode shift travel times for transit users.

MAG has explored Managed Motorways concepts, which are actively used to manage freeways and adjacent corridors in urban areas of the United Kingdom and Australia. These concepts are similar to ICM and ATM implementations in the United States, in that they integrate technology and operational processes to coordinate traffic operations and manage travel demand at the corridor level, and when peak demand is at its highest. Some examples of technologies that are typically part of a Managed Motorway include variable speed limits, adaptive ramp metering, lane control systems and monitoring systems (including cameras and detectors). In addition to technology and operations strategies, managed lane policies are also part of several Managed Motorways programs. MAG initially started exploring Managed Motorways concepts as part of the MAG Managed Lanes Network Development Strategy. Phase 1 of the strategy was completed in 2013 and has since moved on to pilot implementation of advanced ramp metering strategies on SR-51 in 2017.

On the freeway, technologies could support collection of real-time condition data including speed, travel times, congestion and queues. These data would help identify congested freeway conditions and would be used as an input in determining whether an arterial detour is needed. The data would support calculation and posting of comparative travel times to allow travelers to make informed decision about their routes and mode of travel. Additional DMS infrastructure would allow more frequent dissemination of traveler information along the freeway. One key audience for traveler information is freight operators, who could be alerted of network conditions ahead of them and the anticipated impacts on their routes based on real-time information. CCTVs would be placed where necessary to provide complete surveillance coverage of the freeway throughout the corridor, including all entrance and exit ramps. The necessary communications infrastructure would be in place to support seamless communications between freeway devices and the ADOT TOC.

To provide enhanced traffic management on the freeways, adaptive ramp metering technologies would be deployed on all freeway entrance ramps, where implementation of ramp metering rates would be informed by real-time conditions data collected on the freeway main line, ramp and interchange associated with the ramp. Connectivity between the ramp and the interchange traffic signal would be established so they could work in concert to improve traffic flow onto the freeway without negatively affecting traffic on adjacent arterial streets.

Arterials designated as detour routes, and those that cross the freeway, would be outfitted to support the rerouting of freeway traffic onto the arterial network in the case of a freeway closure or severe restrictions to freeway operations. The arterials identified as potential detour routes would be equipped to collect and provide real-time condition data, such as speeds, travel times and queues. These data would support the selection of the detour route and allow for calculation of arterial travel times. The arterials would have complete surveillance coverage at all major intersections to monitor the detour routes at all times. Route guidance infrastructure would be in place at major decisions points along the arterial detour options to support wayfinding by travelers when detours are implemented. All the infrastructure deployed on these designated arterials would have communications that connect them either to the ADOT TOC or a local TMC to allow for remote operation and management.

To provide enhanced traffic management on arterials within the corridor, all traffic signals including freeway interchanges would have the technology and communications to support coordinated traffic signal operations. Interoperability between signals would be available and operated by different agencies, using a central DSS so that corridor-based timing plans could be generated to reduce delay and improve traffic flow along the Spine corridor. Arterial traffic signals along the corridor would support adaptive signal control, which would support more dynamic, coordinated and condition-driven signal timing along corridors. These advanced operations would facilitate improved arterial traffic flow based on real-time traffic condition data collected by arterial devices. These systems would also support improved signal operations where higher volumes of truck traffic enter or exit freeway ramps. Key locations include I-17/7th Avenue, I-17/19th Avenue and I-10/Broadway Road.

Enhanced monitoring and traveler information along the freeway and arterial networks would support the improved movement of all users through the system, including personal vehicles, freight, transit and bicycles/pedestrians that will use or cross the network.

7.7.2 Enhanced Multimodal Intersection Safety Concept

In coordination with traffic interchange improvements and construction of bicycle and pedestrian bridges across the freeway, this concept would deploy technologies to improve safety of bicyclists and pedestrians in the intersection and to improve the intersection's efficiency as it balances multimodal demands.

This traffic signal has a bicycle signal head showing bicyclists when it is safe to cross the intersection.

Intersections in the corridor, including freeway interchange intersections, would be equipped with technology to support the automatic adjustment of traffic signal timing based on pedestrian demand; this would occur in conjunction with adaptive signal timing. This would involve detection within the sidewalk and crosswalk that provides data on the approximate number of pedestrians waiting to cross the intersection at a certain leg. The software would trigger an extension of the pedestrian cross phase when large numbers of people are waiting, allowing more people to cross the road during that phase. Additionally, the detection can cancel the pedestrian crossing phase if it detects that a pedestrian who has activated the crossing button is no longer present (that is, if he or she crossed the road in a different direction, crossed outside of the pedestrian crossing phase or decided not to cross the road at all). This application would increase the efficiency of the crosswalk by not activating the complete pedestrian crossing phase if it is not needed.

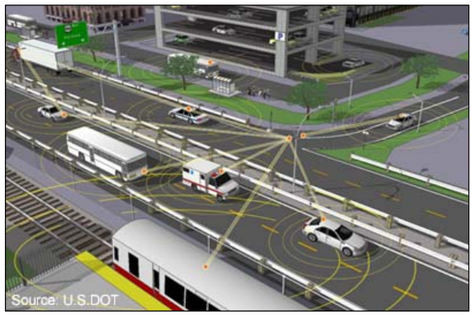
Intersections would also be equipped with advanced sensors combined with radar-type detection to specifically detect bicyclists in a travel lane. When a bicyclist is detected, the signal timing would be triggered (if the signal is in the red phase) or the green time would be extended (if the signal is in the green phase) to allow the bicyclist enough time to pass through the intersection. This would eliminate the challenges of bicyclists not being able to trigger detection at intersections and the need for bicyclists to cross traffic to push the pedestrian push button.

To improve bicyclist safety at intersections, bicycle signal heads would be installed that provide specific phasing information to bicyclists about when they can enter the intersections. The bicycle signals would be incorporated into existing intersections and the timing and phasing would be coordinated with the regular signal, but with timing and phasing that best accommodates bicycle movement. These signal heads would exist at locations where newly constructed bicycle/pedestrian bridges meet an arterial and at all reconstructed intersections along the Spine corridor.

This concept could be piloted at specific locations with higher crash rates involving bicycles and pedestrians prior to full implementation. Potential locations include: 19th Avenue, 27th Avenue, 35th Avenue, Priest Drive/University Drive, 7th Street/McDowell Road and Kyrene Road/Baseline Road. An outreach and education program would be needed to alert pedestrians and bicyclists about the new technology. These technology enhancements would be in addition to design and operations countermeasures (crosswalk striping and marking, signs or bicycle lane striping).

7.7.3 Connected and Autonomous Vehicle Concept

This concept would include deploying technology and systems that support connected and autonomous vehicle operations as they become more prevalent in the future. Much of the research and pilot testing to date has focused on systems for connected vehicles. It is not yet known whether any systems will be needed to enable autonomous vehicles, since many companies are already testing such vehicles with limited coordination with agencies and no new equipment deployed by agencies.



Technology systems that support connected and autonomous vehicles would communicate with various types of vehicles.

Connected vehicle applications have the potential to improve detection of incidents and the impact of incidents, identify and provide advanced warning of road hazards, improve real-time control and coordination of traffic signals and ramp meters, support lane control strategies and provide robust data about real-time conditions. Several of these applications are applicable to the Spine corridor and will require a vehicle-to-infrastructure interface. To enable data transmission between roadside equipment and vehicles, DSRC radios would need to be installed on both the freeway and adjacent arterials. DSRC enables reliable, high transmission rate, low latency and secure communications, and is a more likely choice for safety-driven applications (intersection collision warning) than using a different communications method, such as Wi-Fi or cellular. Both Wi-Fi and cellular are less secure and could be affected by the density of

equipped vehicles, increased latency of data transmission and network vulnerabilities. Lower-risk applications, such as wide area broadcast announcements, emissions monitoring and even ramp metering could potentially leverage cellular or Wi-Fi communications.

ADOT plans to install DSRC radios on I-17 as part of an expansion of the SMART*Drive* Connected Vehicle Test Bed in Anthem. These will be installed on existing structures, sign gantries and posts, light posts and other similar structures. DSRC radios have a range of approximately 1,000 feet. Existing data servers will be configured to take in the data and process it for use by traffic control and management systems. It has not yet been determined whether the freeway DSRC will interface locally at equipment (such as ramp meters or DMS).

Expanding the DSRC capabilities to adjacent arterials would require additional radios and system upgrades at local agencies. Connected vehicles have the potential to address a major gap in today's operations—the lack of real-time congestion and travel information on arterials.

7.7.4 Wrong-Way Driving Detection and Warning Concept

This concept would extend the limits of the I-17 Wrong-Way Detection Deployment Pilot Project, which is scheduled to be constructed on I-17 between SR-101L and I-10 in 2017. It will allow the ADOT TOC and DPS to detect a wrong-way driver who is entering or already driving on the freeway in the wrong direction and allow them to activate responses to warn other drivers on the corridor.

On freeway exit ramps, including freeway-to-freeway transition ramps, detection technology would detect a wrong-way driver at the top of the ramp (near the interchange) and at the bottom (gore point). Also at the gore point, equipment would provide high-quality, visual confirmation of a wrong-way vehicle that also provides identifying characteristics of the vehicle and driver to help the TOC and DPS find the vehicle on the roadway. Dynamic signs placed on the exit at the gore point that are triggered by the detection of a wrong-way driver would provide a visual warning to the driver that he or she is driving the wrong way.

On the freeway main line, detection technology would be deployed that could detect a wrong-way driver and provide an alert to the ADOT TOC. Additional dynamic message boards would provide information and warnings to right-way drivers of wrong-way drivers on the corridor at a greater frequency than the current 3-mile intervals at which DMS are spaced. Complete surveillance along the freeway would allow remote monitoring of the main line and exit ramps within the corridor by the ADOT TOC.

Communications equipment would be in place to allow all equipment on the main line, the ramps (entrance ramps, exit ramps and freeway-to-freeway transition ramps) and at the freeway interchange to communicate with the ADOT TOC so that they can be remotely monitored and operated.

7.7.5 Nontechnology Operational Approaches

The operational approaches described below are recommended to support implementation of the technology approaches. The strategies fall into two categories: staffing resources and coordination and collaboration.

7.7.5.5 Staffing Resources

- **Regional ITS maintenance support**: Create dedicated staff positions to support proactive maintenance and operational reliability of ITS and technology investments on the Spine corridor. Anticipated to be a 10-year contract for staff and should include provision of continuous training and education as technologies change and evolve.
- **Emergency response services**: Expand the FSP, ALERT and REACT to provide greater availability and frequency of service along the Spine corridor. This would involve increasing staff numbers and the availability of emergency response equipment used to respond to events by each team.
- **Regional corridor manager**: Identify a dedicated staff member to focus on operations and management of the Spine corridor. This includes freeway and local traffic management, incident response and support resources (ALERT, FSP, law enforcement), project prioritization and programming and maintenance.

7.7.5.6 Coordination and Collaboration

- **Regional DSS**: Develop and integrate a centralized DSS for the region, which would use real-time data from freeways, arterials and transit along the corridor and recommend a set of strategies to optimize operations in the corridor. This would include a combination of agency and third-party data. The strategies would include freeway, arterial and transit strategies that work coherently and collectively to move traffic efficiently and safely through the corridor. Strategies for each facility would be predetermined and agreed upon by all agencies involved, and partner agencies would also decide whether the recommended set of strategies would be automatically deployed throughout the corridor or whether they would be manually accepted and deployed by each agency.
- **Shared operations agreements**: Formal agreements to support 24-hour-per-day, 7-day-per-week operations of all freeway and arterial roadways within the Spine corridor would provide full coverage for critical corridors. This includes agreements and standard procedures that allow local agencies to operate their respective operations and manage equipment and systems within the corridor during business hours while allowing the ADOT TOC to implement agreed-upon strategies for arterials after business hours.
- **Message library**: Create an agreed-upon message library for DMS, social media postings, and 511 alerts to standardize messaging along the corridor between freeway, arterial and transit agencies. This would support consistent messaging to travelers about corridor conditions, including advanced notification of lane restrictions or alternate routing options, across jurisdictional boundaries, between the modal network (e.g., freeways, arterials and transit) and through multiple media outlets (e.g., DMS, social media and 511).

7.8 Implementation Recommendations and Cost Opinions

Implementation recommendations have been developed that factor in planned enhancements, as well as considering strategies that could be phased in over time. Several stakeholders, including MAG, ADOT, MCDOT, cities and public safety agencies, had input to different strategies and needs as part of structured focus group discussion during the I-10/I-17 Corridor Master Plan study. In parallel with that project, MAG is also preparing a Systems Management and Operations Plan for the region, and that plan identified ICM as a regional priority. There is a strong correlation between the Spine technology recommendations and those that are emerging from the MAG Systems Management and Operations Plan.

Corridor segments are shown in Figure 7-1, and these segments are consistent with other recommendations in the I-10/I-17 Corridor Master Plan.

Table 7-1 summarizes the infrastructure and systems included in the recommended concepts.

Figure 7-1. Spine Corridor Segments

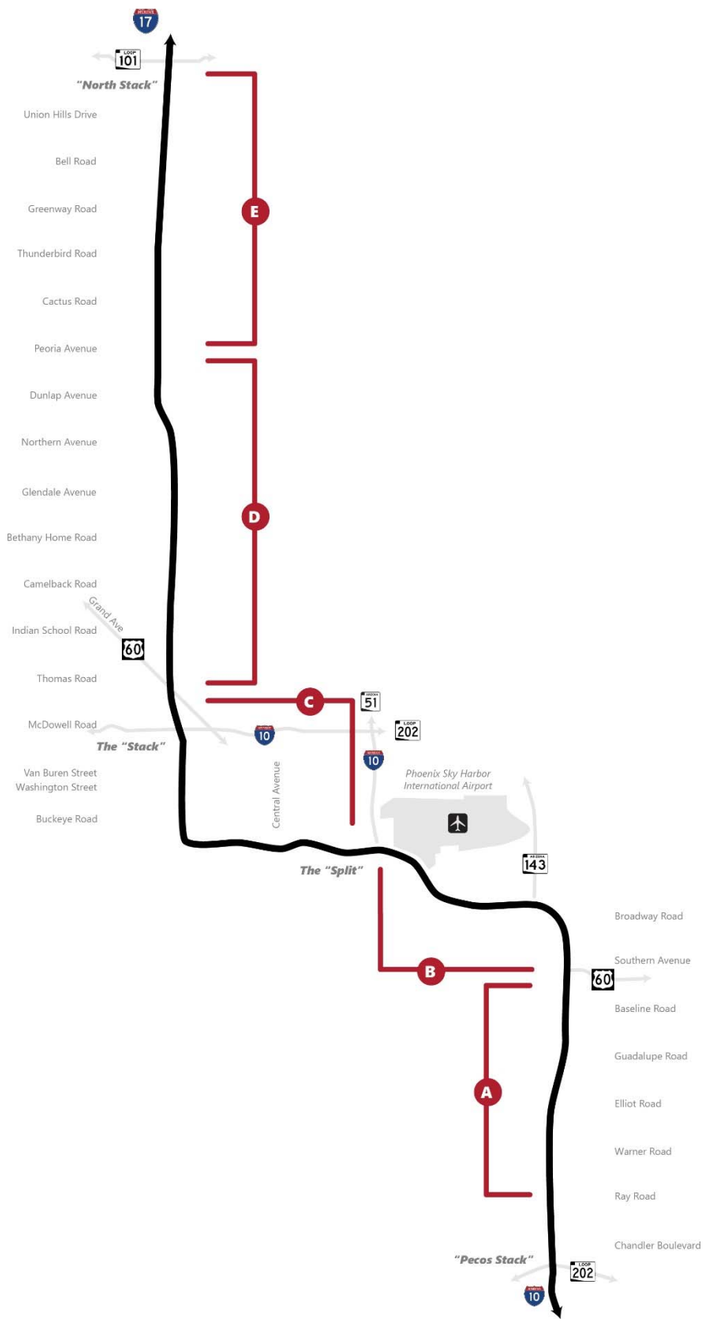


Table 7-1. Summary of Technology Recommendations and Uses

Technology	Description and Use
Enhanced Freeway and Arterial Management Concept	
Arterial communications infrastructure	Fiber and wireless network that provides for stable communications connections between all ITS infrastructure and a central management system on key arterials.
Arterial detection	Detection infrastructure—including existing detection (loops, video identification detection and Bluetooth) and ARID to fill gaps—that supports the collection of travel time and speed data. Data would be used to provide more comprehensive and real-time traveler information for arterials. Recommended deployment at all major-major intersections along potential detour routes and at all freeway traffic interchanges for contiguous coverage.
Arterial detour wayfinding infrastructure	Signs to support detour wayfinding to safely route traffic from freeways to arterials and back to the freeways. Would include static signs at all major decision points along an arterial detour route.
Arterial detour surveillance infrastructure	CCTV cameras to support surveillance of corridor routes, especially during freeway-arterial detouring to make sure that the routes remain safe and free of hazards. Surveillance would also support faster identification and response to incidents and infrastructure malfunctions on these routes.
Arterial detour messaging infrastructure	DMS that can be changed remotely in real time to support traveler information, including posting comparative travel times for freeways and arterials, providing information to support detour routing and providing general traveler information for the Spine corridor.
Adaptive signal control	Central system that would collect and analyze data from arterial detection to determine and implement the optimal signal timing and phasing for traffic signals along a corridor. The system would undergo this analysis and optimization process every few minutes to keep traffic flowing smoothly and to reduce unnecessary delay at intersections. Would help address signal operations needs for vehicles and for trucks.
Freeway ATM side-mounted DMS	Side-mounted DMS along the freeway located every mile in between the existing overhead DMS, which are spaced roughly every 3 miles in each direction. Signs would be mounted in the median or on the shoulder to provide traveler information on corridor travel times, mode shift messaging, incident notifications, detour routing or other messaging opportunities, such as wrong-way driver warnings.
Adaptive ramp metering	Adaptive ramp metering software that is informed by detection along ramps and the main line to implement conditions-responsive and coordinated ramp metering rates throughout the corridor. This would improve traffic flow and throughput on the freeway.
Enhanced Multimodal Intersection Safety Concept	
Bicycle signal head	Install a new signal head at existing traffic signals to provide bicycle-specific timing and phasing. Modifying signal phasing to accommodate bicycles and providing specific instructions to bicyclists for navigating the intersection would facilitate safer crossing for bicyclists and less conflict with vehicles.
Bicycle intersection detection	Microwave detection and presence sensors that, together, allow for bicycle-specific detection at intersections. When a bicycle is detected, the signal system would be triggered to provide time for bicyclists to use the intersection (shown via the bicycle signal head described above) safely.
Pedestrian adaptive traffic signal timing	Enhanced pedestrian crossing buttons, pedestrian detection and signal software modifications that allow for detection of the number of people waiting to cross an intersection so that more crossing time would be allocated if a large number of people are detected waiting to cross. The application would also allow for limiting or canceling the pedestrian phase, even after it is activated with the push button, if it confirms that a pedestrian is no longer waiting to cross.

Technology	Description and Use
Connected and Autonomous Vehicle Concept	
Connected vehicle equipment	Would incorporate technology, including DSRC radios, infrastructure and systems required for future connected and autonomous vehicle operations. This would have broader impacts on other freeway and arterial networks in the region.
Wrong-Way Detection Deployment	
Wrong way driving detection and warning components	This would extend the wrong-way driving application along I-17 north of I-10 to the south along the Spine corridor and would include thermal video detection at the top of and at the gore of all exit ramps, along with fixed high-definition cameras for views of exit ramps.
Nontechnology Operational Approaches	
Regional DSS	Software package that could collect and assimilate real-time corridor data from freeways, arterials and transit to identify appropriate traffic management strategies that collectively allow the corridor to operate most efficiently and safely based on current conditions. Supporting a DSS would require establishing predefined operational strategies for multiagency operations during full freeway closures, including traffic signal operations and timing, coordination with law enforcement in the field, preferred routes for detours and transit operations. Through the system, real-time freeway and arterial information could be made available to TOC/TMC staff and be integrated into publicly available traveler information. A DSS would also support performance management by making real-time information available to support strategy implementation by freeway, arterial and transit operations agencies.

7.8.1 Estimated Implementation Cost Opinion

The total cost opinion for implementing all recommendations in the table would be $47 million (Table 7-2). Baseline equipment costs for each technology deployment recommendation are provided in Table 7-3. The cost opinions were broken down by corridor segments, corresponding to the segments established in the NAR.

Table 7-2. Summary of Total Costs

Freeway Corridor Segment: Segment Length:	A 5.5 miles	B 5.5 miles	C 7 miles	D 6.75 miles	E 6.75 miles
Total per corridor segment	$6,478,905	$5,197,468	$10,105,328	$10,620,635	$10,629,785
Total per mile per segment	$1,177,983	$944,994	$1,443,618	$1,573,427	$1,574,783
Total for Spine corridor	**$47,282,121**				

The cost opinions do not include engineering or installation; each recommendation, either deployed individually or gathered into packages, would need to incorporate below-the-line costs including engineering, contingencies, administrative fees and other items such as traffic control, which would add 55 percent to the baseline cost of equipment. Some cost savings could be realized by coordinating implementation with other improvements in the corridor. Ongoing maintenance and operations also are not part of the cost opinions.

Table 7-3. Spine Corridor Technology Recommendation Cost Opinions

Freeway Corridor Segment: Segment Length:			A 5.5 miles	B 5.5 miles	C 7 miles	D 6.75 miles	E 6.75 miles	$ per mile
Regional								
Regional ITS maintenance contract	Each	$150,000	Included	Included	Included	Included	Included	
Regional corridor manager (dedicated staff)	Each	$100,000	Included	Included	Included	Included	Included	
Parallel corridor signal timing detour plans	Each	$150,000	Included	Included	Included	Included	Included	
DSS software package	Each	$4,000,000	Included	Included	Included	Included	Included	
Total Regional Initiatives			**$4,400,000**					**$139,682**
Freeway								
Freeway ATM side-mounted DMS	Each	$160,000	5	5	5	8	7	
		Total	$800,000	$800,000	$800,000	$1,280,000	$1,120,000	$152,381
Freeway detector for lane	Each	$2,145	22	16	24	23	13	
		Total	$47,190	$34,320	$51,480	$49,335	$27,885	$6,673
Freeway CCTV	Each	$41,050	5	1	1	6	6	
		Total	$205,250	$41,050	$41,050	$246,300	$246,300	$24,760
Freeway wrong-way driving detection	Each TI	$194,333	5	6	6	0	0	
		Total	$971,665	$1,165,998	$1,165,998	$0	$0	$104,878
Freeway connected vehicle infrastructure (DSRC radio)	½ mile	$7,000	12	12	17	16	14	
		Total	$84,000	$84,000	$119,000	$112,000	$98,000	$15,778
Freeway adaptive ramp metering	Each TI	$2,500	6	4	7	7	6	
		Total	$15,000	$10,000	$17,500	$17,500	$15,000	$2,381
Total Freeway Initiatives			**$9,665,821**					**$306,851**
Arterial								
Parallel corridor signal timing re-optimization	Each TI	$150,000	29	23	53	64	55	
		Total	$145,000	$115,000	$265,000	$320,000	$275,000	$35,556
Arterial surveillance (CCTV)	Each	$7,000	10	7	27	25	31	
		Total	$70,000	$49,000	$189,000	$175,000	$217,000	$22,222
Arterial detection (ARID)	Each	$3,400	12	9	17	15	24	
		Total	$40,800	$30,600	$57,800	$51,000	$81,600	$8,311
Intersection bicycle detection	Each	$4,500	12	9	17	15	24	
		Total	$54,000	$40,500	$76,500	$67,500	$108,000	$11,000

Freeway Corridor Segment: Segment Length:			A 5.5 miles	B 5.5 miles	C 7 miles	D 6.75 miles	E 6.75 miles	$ per mile
Arterial messaging (DMS)	Each	$114,000	12	9	24	31	34	
		Total	$1,368,000	$1,026,000	$2,736,000	$3,534,000	$3,876,000	$398,095
Arterial wayfinding sign assembly	Each	$40,000	38	29	59	73	74	
		Total	$1,520,000	$1,160,000	$2,360,000	$2,920,000	$2,960,000	$346,667
Arterial connected vehicle infrastructure (DSRC radio)	Each	$7,000	29	23	53	64	55	
		Total	$203,000	$161,000	$371,000	$448,000	$385,000	$49,778
Bicycle signal head at intersection	Each	$10,000	10	3	1	5	5	
		Total	$100,000	$30,000	$10,000	$50,000	$50,000	$7,619
Adaptive signal control (+ pedestrian crossing application)	Each	$40,000	19	10	41	30	26	
		Total	$855,000	$450,000	$1,845,000	$1,350,000	$1,170,000	$180,000
Total Arterial Initiatives			**$33,366,300**					**$1,059,248**

7.8.2 Implementation Timeframes and Phasing

All of the technology and operations recommendations could be implemented in the near-term, since they do not require major retrofit of the roadway and are generally low-cost improvements compared with large reconstruction projects. Most of these projects will fall into the categorical exclusion category; any equipment will be in addition to what is already in the ADOT or local agency ROW, or will be part of a system enhancement that does not require environmental clearances or approvals.

7.8.3 Infrastructure Recommendations

The recommendations could be implemented individually or in packages, but they could also be implemented as part of larger construction projects, such as those programmed for the Spine corridor in the near-term or any of the near-term recommendation projects that have resulted from the I-10/I-17 Corridor Master Plan. For example, for projects that involve widening the freeway, installing in-pavement detection as part of that project would help avoid having to cut into the pavement later, thus resulting in time and cost efficiencies. The same concept is true for installing fiber communications along corridor arterials; any time that there is trenching or disruption of pavement, conduit and fiber should be installed to avoid having to re-trench and repave the roadway at a later time. During interchange reconstruction projects, opportunities to deploy many of the recommended technology components have been identified, including ARID, CCTV cameras and DMS or wayfinding signs.

There are also efficiencies to including technology in larger projects, rather than keeping them as separate projects, by avoiding the duplication of below-the-line costs, such as administrative fees, contingencies and traffic control. With this consideration, Table 7-4 provides information about projects that are programmed and included in the MAG RTP for construction by 2025 and should be leveraged to include implementation of relevant technology recommendations.

Table 7-4. Programmed Projects in Relation to Technology Recommendations

Fiscal Year	Project Description	Corridor Segment	Relevant Technology Recommendations
2019	Adding general purpose lanes and reconstructing traffic interchanges on I-10 between the I-17 Split and SR-202L	A, B	All freeway recommendations and inclusion of fiber (as needed), arterial detection, CCTV, wayfinding and DMS at interchanges, arterial improvements
2019	Reconstructing the I-17/Central Avenue traffic interchange	C	Fiber (as needed), arterial detection, CCTV, wayfinding and DMS, arterial improvements
2020	Reconstructing the I-17/Camelback Road traffic interchange	D	Fiber (as needed), arterial detection, CCTV, wayfinding and DMS
2024	Adding an HOV lane and reconstructing traffic interchanges on I-17 between the Split and Thomas Road	C	All freeway recommendations and inclusion of fiber (as needed) arterial detection, CCTV, wayfinding and DMS at interchanges
2024	Reconstructing the I-17/Indian School Road traffic interchange	D	Fiber (as needed), arterial detection, CCTV, wayfinding and DMS

During the planning and engineering of each of these projects, the relevant technology recommendations in this document should be considered for inclusion in the project.

A similar approach should be considered for all projects that result from this Spine study, including the freeway reconstruction projects, the traffic interchange reconstruction projects, the transit projects and the bicycle and pedestrian projects. Freeway and interchange projects should follow the considerations discussed above. The transit and bicycle/pedestrian projects that can be relevant for inclusion of technology largely consist of intersection improvements on existing arterials and freeway interchanges. Similar to the recommendations for including technology in interchange reconstructions, these intersection enhancements are a good opportunity to deploy technology that is recommended for intersections, including fiber (if needed), detection, CCTV, wayfinding signs and DMS. There is also the opportunity to deploy DSRC radios at intersections, but this should be considered only if a deployment will occur along a series of intersections along a corridor, rather than a single, isolated radio deployment.

7.8.4 Operational Recommendations

Multiple operational recommendations included in this chapter would not involve infrastructure deployment or construction, but would require time and money to develop and implement. For example, all of the regional operations recommendations, such as establishing a corridor manager staff position or establishing a regional maintenance contract for ITS devices, could be started immediately and would not have the constraints related to the project development process. However, they need to be budgeted at a regional level, either through an entity such as MAG or through a type of pooled fund with all agencies in the region. This is especially true for the staff position and maintenance contract because they would have an ongoing cost, as opposed to a one-time cost.

The other operational recommendations—including developing a DSS, re-optimizing corridor signal timing and developing detour routing plans for the corridor—would involve coordination and partnership and would provide regional benefits that extend outside of the Spine corridor. As such, MAG, ADOT or MCDOT should lead these efforts as agencies with regional influence and a regional focus. They should be considered for inclusion in the MAG Unified Planning Work Program, the TIP and the future RTP.