ITS CONCEPTS FOR RURAL CORRIDOR MANAGEMENT

Final Report 615

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16. Abstract

The Arizona Department of Transportation’s (ADOT) *SPR-570: Rural ITS Progress Study - Arizona 2004* provided 20 key recommendations for improved utilization of the rural ITS (Intelligent Transportation Systems) infrastructure. Two years later, in reviewing the outcomes of the 2004 study and the ongoing rural technology deployments, the Department identified several of the key concerns as still being unresolved. In general, ADOT has been successful in implementing the recommendations of the 2004 statewide review, but five areas of unmet needs or unfulfilled potential remain. These five gap areas are the primary focus of this new research project, to fully implement the potential of all of the recommendations from the 2004 study.

The five primary focus areas are: ITS Maintenance, Weather Information Systems, Highway Advisory Radio, Motorist Assist Patrols, and Information Sharing. The research team interviewed the project’s stakeholders from Arizona’s rural districts to identify recent changes in their ITS deployment, goals, and visions for future deployment, as well as current needs and desires since the previous 2004 study. The investigators also reviewed the current practices and concepts of rural ITS among other transportation agencies throughout the country. This included conducting personal interviews with recognized industry leaders, attending industry conferences, and performing extensive research in literature, products (both off-the-shelf and in-development), and on-line.

Based on the interviews and state-of-the-practice research components, the investigators developed a list of ITS concepts that might service the rural needs of the Department. Each of the five focus areas contains several concepts that address needs identified as original project goals, or new topics identified during the field interviews. Each discussion section provides a conceptual approach and application of ITS technology or state-of-the-practice development, a breakdown of benefits and challenges for implementation, implementation recommendations, and a breakdown of the engineer’s opinion of cost. Each concept has been ranked by the project advisory group based on implementation priority. A potential process owner and potential resources for deployment are also identified.

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SI (MODERN METRIC) CONVERSION FACTORS*

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	Square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	Cubic feet	0.028	cubic meters	m^3
yd^3	Cubic yards	0.765	cubic meters	m^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000lb)	0.907	megagrams (or “metric ton”)	mg (or “t”)
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE AND PRESSURE OR STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
mg (or “t”)	megagrams (or “metric ton”)	1.102	short tons (2000lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS		
N	Newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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ABBREVIATIONS AND ACRONYMS

Term	Definition
4WD	Four Wheel Drive
ADA	Americans with Disabilities Act of 1990
ADOT	Arizona Department of Transportation
ADT	Average Daily Traffic
ADOT-ALERT	Arizona Local Emergency Response Team
ALERT	Automated Local Evaluation in Real Time (weather data)
AM	Amplitude Modulation
ATRC	Arizona Transportation Research Center
AVL	Automatic Vehicle Location technologies
AWOS	Automated Weather Observing System
BOR	Bureau of Reclamation
CAD	Computer Aided Dispatch
CCP	Communications & Community Partnerships (ADOT)
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CHP	California Highway Patrol
CITE	Consortium for ITS Training and Education
CMML	Canadian Meteorological Mark-up Language
DMS	Dynamic Message Sign *(alternate to VMS: Variable Message Sign)*
DOT	Department of Transportation
DPS	Department of Public Safety (Arizona Highway Patrol)
DSRC	Dedicated Short Range Communications
DTN	Data Transmission Network
DUI	Driving Under the Influence
EB	Eastbound
EOC	Emergency Operations Center
EPIC	Expedited Processing at International Crossings
ESS	Environmental Sensing Station
ETA	Estimated Time of Arrival
FAST	Freeing Alternatives for Speedy Transportation
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FM	Frequency Modulation
FMS	Freeway Management System
FSP	Freeway Service Patrol
FTE	Full-Time Employee
FY	Fiscal Year
GPS	Global Positioning System (Satellite)
HAR	Highway Advisory Radio
HCRS	Highway Condition Reporting System
I-[#]	Interstate [Number]
IGA	Intergovernmental Agreement

ITI	Intelligent Transportation Infrastructure
ITOC	Interim Traffic Operations Center
ITS	Intelligent Transportation System
kHz	Kilohertz
KM	Kilometer
LED	Light Emitting Diode
LTAP	Local Technical Assistance Program
MAP	Motorist Assist Patrol
MDSS	Maintenance Decision Support System
MP	Mile Post
MHz	Megahertz
MVD	Motor Vehicle Department
NAB	National Association of Broadcasters
NAFTA	North American Free Trade Agreement
NB	Northbound
NOAA	National Oceanic & Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
O&M	Operating and Maintenance
ODOT	Oregon Department of Transportation
PAD	Passive Acoustic Detector
PAG	Pima Association of Governments
PR	Public Relations
PTZ	Pan/Tilt/Zoom
RWIS	Road Weather Information System
SB	Southbound
SPR	State Planning and Research
SR [#]	State Route [Number]
TB	Trailblazer Sign
TI	Traffic Interchange
TIS	Traveler Information System
TOC	Traffic Operations Center
TTG	Transportation Technology Group
TV	Television
UDOT	Utah Department of Transportation
US [#]	United States Highway [Number]
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VHF	Very High Frequency
WB	Westbound
WIM	Weigh-In-Motion
WIS	Weather Information System
WYSIWIG	“What You See Is What You Get” (graphic interface format)
YTD	Year to Date

EXECUTIVE SUMMARY

BACKGROUND

Large-scale planning and deployment of modern Intelligent Transportation System (ITS) technology in rural areas by the Arizona Department of Transportation (ADOT) essentially began with a 1997 project to create the *Strategic Plan for Early Deployment of Intelligent Transportation Systems (ITS) on (the) Interstate 40 Corridor*.[1] This initial effort was followed in late 1998 by the *Strategic Plan for Statewide Deployment of Intelligent Transportation Systems in Arizona*.[2] Deployment elements of the strategic plan were also regularly updated between 1997 and 2002 in the ADOT Transportation Technology Group's internal *Statewide Plan – Intelligent Transportation Infrastructure.*

ADOT soon recognized the need to measure progress, and to better define the ITS issues that are specific to the rural highway environment. Another research project was initiated, the *Rural ITS Progress Study – Arizona 2004.*[3] This project measured the performance and documented the benefits of all currently deployed systems, and developed 20 key recommendations for improved utilization of ADOT's rural ITS infrastructure.

ADOT has been successful in implementing the recommendations of the 2004 statewide review, but five areas of unmet needs or unfulfilled potential remain. These five areas - ITS maintenance, weather information systems, highway advisory information, motorist assist patrols, and internal information sharing - are the primary focus of this research project. The further development of ITS concepts related to these five focus areas is an effort to fully implement the potential of all of the recommendations from the 2004 study.

The project's primary focus is to review and recommend ITS concepts that can be applied in rural regions of the state to better meet the needs of ADOT. The objectives are to:

- Document the existing conditions of rural ITS deployment for the Department.
- Identify the stakeholders' needs that ITS can address.
- Research state-of-the-art technologies and business practices being used throughout the nation by other agencies.
- Develop ITS concepts that can be deployed in Arizona's rural settings.
- Develop an Implementation Plan prioritizing those ITS concepts.

This study will enable ADOT to build from their experience with new technologies and business practices as they relate to all of Arizona's rural ITS program.

DISTRICT NEEDS

The initial tasks for this study were to review the implementation status of all of ADOT's rural ITS infrastructure elements statewide through June 2007, and to document District needs that ITS can address. The information was collected through interviews with senior staff in all of the Department's rural districts, and its Transportation Technology

Group (TTG). The participants in the interview process represent the core of ADOT's rural district management including all of the District Engineers and many Maintenance Engineers, Development Engineers, Traffic Engineers, Maintenance Superintendents and Supervisors.

The questions solicited information regarding recent deployments or decommissioning of ITS devices, planned elements to be installed, and ITS needs. Topics varied from district to district, but generally included Dynamic Message Signs (DMS), 511 traveler information, highway advisory radio (HAR) or traveler information stations (TIS), road weather information systems (RWIS), motorist assist patrol (MAP) programs, closed-circuit television (CCTV) cameras, passive acoustic detectors (PAD), license plate reader systems, speed detection and warning systems, oversize/overweight permitting, instrumented truck escape ramps, and roadside callbox systems.

Of the five focus areas, ITS maintenance and weather information systems were identified by all of the Districts as most important. Each District identified a particular vision for ITS programs and deployment, as well as individual ITS needs. Some of these needs were identified as being corridor-specific. The collected information indicated that there are regional needs that cross district boundaries, relating to varying storm and weather effects, incident detection and highway monitoring, and relaying traveler information to the public.

STATE-OF-THE-PRACTICE INVESTIGATION

The needs defined during the District interviews provided direction for the next task of the project, which was to conduct research on current ITS deployment technologies and business practices by public agencies nationwide. This included reviews of technology and business plans used for innovative rural ITS systems to help identify the state-of-the-art practices to best address the identified concerns of the Department.

The research methods used to collect data and information included conducting a web-based survey of new products and innovations related to rural ITS. The focus areas of the research included: effective ITS maintenance and management practices and tools, weather information systems, highway advisory radio systems, motorist assist patrol fleet and program management, and innovative ITS technology transfer opportunities.

The research effort included web searches focused on federal, state government and DOT websites, on-line searches of transportation libraries, literature review of industry periodicals and pooled-fund studies, and reviews of new vendor products. To learn about some of the latest developments in the rural ITS field and to develop a strong background in the underlying materials, the research team participated in numerous industry conferences including the National Rural ITS Conference in Montana, the Weather and Transportation Workshop in Missouri, the ITS Arizona Conference in Phoenix, and the I-40 Corridor Coalition Meeting in Flagstaff. Interviews were conducted with multiple vendors, field experts, project and maintenance contractors, and other state agencies' technical supervisors for ITS-related experiences.

The principal findings of the research varied from topic to topic. *ITS maintenance research* identified successful third-party contracting for deployed ITS devices in Colorado, where the Department of Transportation (CDOT) has employed an operations and maintenance contractor since 1998 to facilitate its ITS program, showing the benefits of a properly funded and maintained system. Other programs in Florida and Montana have had varying success with operations and maintenance of ITS programs in-house.

Funding of programs, regardless whether performed in-house or out-serviced, remains an issue for agencies as budgetary constraints and delivery of adequate service continue to be challenges. In reviews of other southwestern states, Arizona ranked high in ITS deployment, as other states viewed ADOT deployments as being ahead of the curve.

Arizona's ITS deployment in *weather information systems* also is seen by other agencies as advanced and well-developed. A new contract for Road Weather Information Systems (RWIS) was initiated during the execution of this study, with a third-party contractor responsible for maintaining all of ADOT's RWIS sites, and being paid to deliver data. The research indicated that both state agencies and the traveling public benefit from this weather information, when presented in a user-friendly, accurate and timely manner.

The Utah Department of Transportation (UDOT) employs meteorologists for statewide monitoring of storm systems, and is a model of a single-point source for information and data analysis. National programs such as Clarus will serve as a weather information data collection service for participating states to provide and share weather data. Arizona can view neighboring states' weather data to assess approaching storms. Intergovernmental agreements (IGAs) allow state agencies to share weather data and information, for example, at flood monitoring sites. Mohave County and ADOT have had great success with such an IGA for data sharing.

Other weather technologies investigated include roadway icing monitors, automated anti-icing systems, and low-visibility detection and warning systems. Each of these technologies offers varying ability to assist ADOT in hazardous roadway conditions due to storms, ranging from reactive to proactive processes. Most weather monitoring technologies can be integrated with traveler information systems to alert motorists to changing roadway conditions.

Research on *Highway Advisory Radio* (HAR) resulted in a plethora of options for deployment, from permanent sites to portable units to synchronized services. The goal of information delivery is to reach as many customers as possible with pertinent information in a timely fashion. HAR uses AM radio to broadcast specific messages to motorists on roadway conditions, usually for long-term construction projects. The broadcast range limits the penetration of information delivery, with the Arizona terrain being a challenge for radio service. Numerous agencies have benefited from HAR deployment, as broadcast messages can be modified and changed easily and quickly.

Motorist Assist Patrol (MAP) programs are common in urban and suburban settings throughout the nation, especially for large metropolitan areas with heavy traffic. In rural settings, MAPs are challenged by distance; incident detection and response times are hindered by the long routes and limited manpower. Contracted rural MAP programs are initiated during construction projects to help stranded motorists in work zones. Volunteer programs usually consist of sporadic route monitoring when the participants have time.

Information-sharing opportunities exist in the traffic engineering industry, with both national and state conferences regularly occurring. Several professional societies have a strong presence in Arizona, including the Institute of Transportation Engineers (ITE), the Arizona chapter of the Intelligent Transportation Society of America, and the International Municipal Signal Association (IMSA). These groups, as well as ADOT's Local Technical Assistance Program (LTAP) each offer periodic conferences and diverse training. Even with a multitude of conference opportunities, ADOT staff are always challenged by limited time, excessive travel distance, and budgetary constraints.

The use of ITS for innovative solutions in areas of operational training and commercial vehicle permitting were also reviewed as topics of interest. Oversize loads in particular could be monitored more effectively by ADOT in the future with ITS.

IMPLEMENTATION PLAN & RECOMMENDATIONS

The final task was to develop a detailed implementation plan that integrates numerous ITS deployment concepts into a set of recommendations to ADOT. Each concept relates to one of the five ITS focus areas and addresses original scope-defined goals as well as stakeholder needs from the field interview process. The discussion points on each area include conceptual operations, deployment benefits and challenges, and implementation recommendations and cost basis.

The ITS concepts developed for this study are tabulated below, including an engineers' opinion of the initial capital costs, the annual operations and maintenance costs, and the resulting five-year funding estimate total for each concept.

Engineers Opinion of ADOT Cost for Rural ITS Concepts

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Focus Area: ITS Maintenance				
Third-Party ITS Operations & Maintenance Contracting - $200,000 Annual Contract	Scope	-	$200,000	$1,000,000
Truck Escape Ramp Monitoring - 7 Sites at $125,000 Per Site (Total)	Field	$700,000	$35,000	$875,000
Expansion of Rural Cellular Coverage - Major US Highways & State Routes	Scope	$75,000	-	$75,000
DMS Construction - 8 Sites at $312,500 Per Site (Total)	Scope	$2,300,000	$40,000	$2,500,000

Deployment Concept	**Project Goal**	**Initial / Capital Costs**	***Annual* Operating & Maintenance Costs**	**Opinion of Cost (*Over 5 Years*)**
Focus Area: Weather Information Systems				
Participation in Clarus - Database Development & Maintenance, Coordination with National Agency	Scope	-	$100,000	$500,000
RWIS Deployment - 48 Sites at $112,000 Per Site (Total)	Scope	$768,000	$921,600	$5,376,000
State Meteorologist - 1 Position at $85,000 Annual Salary	Field	-	$85,000	$425,000
Low Cost Weather Stations - 40 Sites at $2,500 Per Site (Total)	Scope	$64,000	$7,200	$100,000
Low Visibility Detection - 15 Sites at $75,000 Per Site (Total)	Field	$900,000	$45,000	$1,125,000
Bridge Deck Anti-Icing Monitoring - 3 Locations at $100,000 / Site (Total)	Field	$240,000	$12,000	$300,000
Develop IGAs for Flood Detection Data - 11 Counties at $70,000 (each)	Field	$770,000		$770,000
Mobile Data Collection for Snowplows - 54 Snowplows at $12,000 / Vehicle (Total), w/ satellite communication.	Field	$540,000	$21,600	$648,000
Focus Area: Traveler Information Systems				
Portable HAR – 8 Units at $30,000 Each (Total)	Scope	$200,000	$8,000	$240,000
Work Zone HAR Specification Development – One-Time Consultant Fee	Scope	$5,000	-	$5,000
Permanent HAR Sites - 20 Sites at $25,000 Per Site (Total)	Scope	$400,000	$20,000	$500,000
Intelligent Rest Area Deployment - 15 Sites at $48,000 Per Site (Total)	Scope	$645,000	$15,000	$720,000
Corridor Travel Time Monitoring - 8 Sites at $112,500 Per Site (Total)	Field	$800,000	$20,000	$900,000
Emergency Detour Routing - 33 EMS at $6,000 Per Sign (Total)	Field	$148,500	$9,900	$198,000

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Focus Area: Motorist Assistance and Safety Services				
MAP Specification Development - One-Time Consultant Fee	Scope	$30,000	-	$30,000
CRASH Vehicles - 20 Vehicles at $90,000 Per Vehicle	Scope	-	$360,000	$1,800,000
Enhance Field Communications with Phoenix District via 800 MHz Radios - 50 Units at $1,500 Per Unit Installed	Scope	$75,000	-	$75,000
ADOT VHF Radios in DPS Vehicles - 440 Units at $1,500 Per Installation - Total $660,000: **All Costs by DPS*	Scope	*	*	$0
District Training Programs - Consultant Fees for Protocol Updates	Field	-	$8,000	$40,000
Focus Area: Information Sharing				
Oversized Load Management - Initial Implementation of System ** System Expansion and On-Going Costs Absorbed by Industry Agencies*	Field	$400,000	*	$400,000
Simulator Interagency Training -LTAP - Supplemental Activities to Establish Coordination with Partner Agencies	Field	-	$12,000	$60,000
Internal Information Sharing - 5 Conferences Per Year for 20 Participants	Scope	-	$50,000	$250,000

Conceptual five-year cost commitments for each of the five ITS focus areas are totaled, and averaged per year, in the following table:

Total Engineers Opinion of ADOT Cost for Rural ITS Concepts

Focus Areas Deployment Concepts	Opinion of Cost
ITS Maintenance	$4,450,000
Weather Information Systems	$9,244,000
Traveler Information Systems	$2,563,000
Motorist Assistance and Safety Services	$1,945,000
Information Sharing	$710,000
TOTAL OVER 5 YEARS	$18,912,000
AVERAGE TOTAL COST PER YEAR	$3,782,400

PRIORITIZATION AND PROCESS OWNERSHIP

The ITS concept recommendations that were developed from this project were prioritized by the Technical Advisory Committee (TAC). Each member was asked to identify the level of priority (high, medium, low) for each ITS concept. In addition, each was asked to identify potential process owners or champions for each ITS concept. Lastly, each TAC member was asked to suggest potential resources for deployment of these concepts.

The following table lists the TAC's recommendations as to key implementation elements, showing who within ADOT may best champion these concepts, and what likely ADOT resources are identified for funding. Some ITS elements may also qualify for Federal-aid construction project funds. The TAC's prioritization level for each of these ITS concepts is also shown.

Prioritization of Rural ITS Concepts

Deployment Concept	Project Goal	Priority	Potential Process Owner(s)	Identified or Potential Resources for Deployment
**Note - Some ITS elements of projects as noted may be eligible for regular Federal-aid construction funding.*				
Focus Area: ITS Maintenance				
Third-Party ITS O&M Contracting	Scope	High	TTG	TTG Funds
Truck Escape Ramp Monitoring	Field	Med	TTG or Districts w/ Ramps	TTG and District Minor Funds*
Expansion of Rural Cellular Coverage	Scope	Med	Right-Of-Way Section	ITD Funding
DMS Construction	Scope	High	TTG / District	TTG or District Minor*
Focus Area: Weather Information Systems				
Participation in Clarus	Scope	High	TTG	TTG Funds*
RWIS Deployment	Scope	Med	TTG or Central Maintenance	TTG and District Minor Funds*
Highway-Focused State Meteorologist	Field	High	TTG	Cost Share Each District
Low Cost Weather Station Deployment	Scope	Med	Central Maintenance	District Minor Funds*
Low Visibility Detection	Field	Med	TTG or District	District Minor or HES*
Bridge Deck Anti-Icing Monitoring	Field	Low	District	District Minor or HES*
IGAs for Flood Detection	Field	Med	State Maintenance Engineer	Maintenance Fund
Mobile Data Collection for Snowplows	Field	Med	Equipment Services	Districts and Equipment Services

Deployment Concept	Project Goal	Priority	Potential Process Owner(s)	Identified or Potential Resources for Deployment
Focus Area: Traveler Information Systems				
Portable HAR	Scope	Med	District	Construction Fund or District Minor*
Work Zone HAR Standard Specifications	Scope	Med	CCP	CCP Fund or State Construction Fund*
Permanent HAR	Scope	High	District	District Minor or Maintenance Fund*
Intelligent Rest Area Deployment	Scope	Low	Roadside Development	Construction Fund (Rest Area Fund)*
Corridor Travel Time Monitoring	Field	High	TTG or Districts	TTG Fund*
Emergency Detour Routing	Field	High	TTG or Districts	TTG Fund
Focus Area: Motorist Assistance and Safety Services				
Standard MAP Specification	Scope	Med	TTG or Districts	TTG Fund*
CRASH Vehicles	Scope	Med	Districts and Equipment Services	State Engineers Office and District Funds for Equipment Services
Enhanced Communication w/ Phoenix Maintenance via 800 MHz Radios	Scope	Med	Central Maintenance	Maintenance Fund
Secondary ADOT UHF Radios for DPS	Scope	Med	DPS	DPS
District Training Programs	Field	Med	State Maintenance Engineer	Maintenance Fund
Focus Area: Information Sharing				
Oversized Load Management	Field	Med	Regional Traffic Engineers	Maintenance Fund
Simulator Interagency Training	Field	High	Districts and LTAP	LTAP and Third Party Funds
Internal Information Sharing	Scope	High	ITD / TTG	ITD & District Funds
**Note - Some ITS elements of projects as noted may be eligible for regular Federal-aid construction funding.*				

1. INTRODUCTION

1.1 BACKGROUND

Large scale planning and deployment of rural ITS by the Arizona Department of Transportation essentially began in 1997 with completion of the *Strategic Plan for Early Deployment of Intelligent Transportation Systems on (the) Interstate 40 Corridor*.[1] This initial effort was followed in late 1998 by the *Strategic Plan for Statewide Deployment of Intelligent Transportation Systems in Arizona*.[2] Periodic updates of the strategic plan have been captured in the ADOT Transportation Technology Group's internal *Statewide Plan – Intelligent Transportation Infrastructure* (ITI), between 1997 and 2002.

ADOT soon recognized the need to measure progress and to better identify those ITS issues specific to the rural environment, and so initiated another research project, the *Rural ITS Progress Study – Arizona 2004*.[3] This study had the following key objectives:

- Measure performance and document the benefits of deployed systems, and of ADOT's rural ITS program.
- Document ADOT's current operating and maintenance costs and issues.
- Determine travelers' perceptions and reactions to Arizona's rural ITS elements.
- Determine how well ADOT had adhered to the 1998 Statewide ITS Plan's vision.

The 2004 study developed 20 key recommendations for improved utilization of ADOT's rural ITS infrastructure. Two years later, in reviewing the outcomes of the 2004 study and the ongoing rural technology deployments, the Department identified five still-unresolved areas of concern. In general, ADOT had been successful in implementing the recommendations of the 2004 statewide review, but five areas of unmet needs or unfulfilled potential remained. The five gap areas, described below, are the focus of this new research to fully implement the potential of all recommendations of the prior study.

As long-term planning and deployment of rural ITS continues in rural Arizona, it would also be of great benefit to review current practices and concepts of rural ITS among other transportation agencies. This new study will enable ADOT to build on their experience in new technologies and business practices as they relate to Arizona's rural ITS program.

1.2 FOCUS AREAS

The following five ITS concepts, issues, and systems are the primary focus of the research workscope for Project SPR 615:

Focus Area 1: Rural ITS Maintenance – Review of options to better address and balance resources, issues, and abilities to support and maintain ITS devices including HAR, DMS, RWIS, CCTV cameras, etc.

Focus Area 2: Weather Information Systems – Resources for weather data such that the districts can manage the appropriate response to severe weather conditions, including snow and ice storms, dust storms, flooding, low visibility, etc.

Focus Area 3: Highway Advisory Radio - Resources to broadcast advisory messages to the traveling public for specific sections of roadway regarding construction or maintenance, or short-term alerts for weather, or traffic restrictions due to incidents.

Focus Area 4: Motorist Assist Patrols – Options for rural service patrols to aid stranded motorists. The emphasis is on clearing vehicles from the travel lanes and assisting motorists in need of fuel, towing, or other emergency services.

Focus Area 5: Sharing of Practical ITS Ideas & Experiences – Options and resources for the districts to review available ITS technologies, including trade publications, regional or national conferences, dialogues with other agencies and districts, etc.

1.3 OBJECTIVES

The project's primary focus is to review and recommend ITS concepts that can be applied in rural regions of the state to better meet the needs of ADOT. The main objectives are to:

- Document the existing conditions of rural ITS deployment for the Department.
- Record the stakeholders needs that ITS can address.
- Research state-of-the-art technologies and business practices being used throughout the nation by other agencies.
- Develop ITS concepts that can be deployed in Arizona's rural settings.
- Develop an implementation plan prioritizing the ITS Concepts.

1.4 REPORT ORGANIZATION

- **Chapter 2** reviews the results from the 2004 study and updates the information regarding ITS deployment statewide.
- **Chapter 3** summarizes stakeholder needs information collected through a series of structured interviews held at each ADOT District Office in late summer and early fall of 2006.
- **Chapters 4 to 8** present research conducted to survey the current ITS deployment technology and business plans in use around the nation, with emphasis on the most promising aspects previously identified.
- **Chapters 9 to 13** compile each of the ITS concepts into an implementation plan, where each concept relates to an identified focus area, with an engineers' opinion of probable cost over a five-year life cycle.
- **Chapter 14** integrates numerous ITS deployment concepts into a summary of conceptual recommendations and program costs that address both the original project goals, and the needs identified by the stakeholders.

2. ITI DEPLOYMENT UPDATE

The initial task for this study was to review the implementation status of all of ADOT's rural ITS infrastructure elements statewide for the fiscal year ending in June, 2007. The information presented in this chapter was collected through interviews with the District Engineers in all of the Department's rural districts, and the ADOT Transportation Technology Group. The information gathering interviews were conducted during the months of August and September 2006. Approximately thirty senior staff members from the rural districts provided the information compiled in this report.

Some of the statistics for utilization of the central ITS systems were provided by the TTG staff. The participants in the interview process represent the core of ADOT's rural district management: all District Engineers and many Maintenance Engineers, Development Engineers, Traffic Engineers, Maintenance Superintendents and Supervisors. The Coconino County Engineer also participated in the Flagstaff session.

The key question asked in the interviews was, "What is new since 2004?" Some of the follow-up questions used to elicit further input included:

- What ITS elements have you installed since 2004?
- Have you removed any ITS elements since 2004?
- What ITS features or elements do you have planned for your District?

Table 1 on the following pages presents the study findings from the Rural ITS Progress Study (SPR 570) conducted in 2004. *All revised or updated information is italicized.* The 2006 "deployment update" column has been added to highlight the significant changes that have occurred since 2004 (as shown in italics).

The matrix presents the rural ITS deployment facts and utilization statistics as of Fall 2006, as reported in the field interviews. The discussion following the matrix describes trends in the utilization of each ITS element, along with the advantages and limitations associated with each of the elements. The discussion of each element concludes with a look towards the future.

Table 1. ITI Deployment Matrix Update

ITS Element	2006 Deployment Update	Outputs	Outcomes/Benefits	Costs
Road Weather Information Systems (RWIS)	• *No additional sites deployed* • *Vendor change in progress* • *Changed from ADOT owned & maintained system to Weather Information Service (data purchase contract)*	Wind, temperature, precipitation, chemical	Plowing & deicing operations; dust storm prediction/warning; additional data for National Weather Service (NWS); traveler safety	*Weather Information Service will cost approximately $1,700 per site per month over the five year term of the Weather Information Service Program.*
Passive Acoustic Detectors (PAD)	• *Eliminated from RWIS sites* • *Used only in Phoenix FMS*	Speed, volume, occupancy	Supplement automatic traffic recorder data; improves employee safety	Integral part of RWIS stations; about $2,500 per unit.
Remote Cameras (CCTV)	• *Now part of RWIS contract except for three DMS sites on I-17 and I-40 which still use the old RWIS infrastructure*	Camera images (still frame)	Verify current weather and pavement conditions; public can access images	Capital cost to install 2 cameras at existing DMS site: $20,000
Speed Detection/ Warning Devices	• *Fixed Warning System remains in place on US 93 north of Kingman* • *City of Prescott Valley has applied for ADOT permits to do photo speed and red light enforcement on SR 69 at three locations.* • *Permit issuance for this speed enforcement is on-hold pending completion of the evaluation of the Loop 101 photo enforcement*	Speed warning messages	Reduced 85^{th} percentile speed 18%; improved safety/reduced repair costs	Capital cost for pilot installation on existing structure - $48,820
License Plate Readers	• *The license plate reader system was removed upon completion of the SR-68 Design-Build Project* • *There are no license plate readers in use in Arizona*	License plate matches (11%- data from 2001)	96% of incentive was collected; improved level of service/reduced delay	Incentive to maintain travel time: <1% of project cost
Highway Condition Reporting System (HCRS)	• *System utilization is expanding* • *2003 Volume: 10,000 entries* • *2004 Volume: 20,000 entries* • *2005 Volume: 30,000 entries* • *2006 YTD Volume (through July): 25,000 entries*	Traveler information entries (12,450/year – 2000 to 2002)	Improved project and emergency communications; traveler information is quickly available to the public	$270,000 to develop HCRS; $62,000/yr for data entry labor; monthly maintenance costs
Traveler Information via Telephone (511)	• *Call volumes rising rapidly* • *62,000 calls per month is now typical* • *Number of inbound lines being increased*	About 344,000 calls / year (data from 2003)	Less demand on public agency staff for information; public relations; better travel decisions; easy to remember	$270,000 to develop voice inter-face; $85,000-system upgrades; $137,000/yr O&M; promotion

*Note: Italicized items represent updates, modifications or changes since the SPR 570 study. *Updated 2006 information is shown in italics.*

ITS Element	2006 Deployment Update	Outputs	Outcomes/Benefits	Costs
DPS CAD System	• *ADOT now has a DPS CAD terminal at the TOC*	*Incident Reports*	*Increased awareness of incidents on the roadway*	*Not applicable*
Traveler Information via Internet: www.az511.com	• *Rising number of hits (19 million hits per month is now typical)*	75 million hits/yr; 10 million page views/yr (data from 2003)	Less demand on public agency staff for information; public relations; better travel decisions; restrictions data access.	System hardware/software development & maintenance costs; promotion costs
Overhead Dynamic Message Signs (DMS)	• *Signs added at an average rate of four signs per year* • *New DMS Vendors Selected* • *LED sign technology now available on state contract* • *Walk-in sign cases now available on state contract* • *Multiple sign sizes now available* • *New signs will be made in USA*	About 8,800 messages/year (data from 2003)	Less demand on public agency staff for information and congestion management; better travel decisions	Capital costs - $385,000; O&M costs - $1,035/$2,478/year
Shoulder-Mounted DMS	• *Removed from US-93 upon completion of construction work*	Speed warnings; steep grades ahead/HAR frequency messages	Safety improvements; lower infrastructure repair costs	Installation - approx. $70,000 per sign; O&M costs – under $1,000/yr (estimated)
Portable Trailer-Mounted DMS	• *In-routine use on all significant construction projects*	Many deployments/ year	Deployment flexibility; ease of set up; better travel decisions.	Solar $925/mo.; diesel $450/mo (Equipment Services rates)
Highway Advisory Radio (HAR)	• *Deployed in Kingman and Holbrook Districts* • *I-40 Winslow TI construction project usage* • *US-93 Truck restrictions at Hoover Dam* • *Use of HAR has reduced the number of truck turn-arounds at the dam* • *Routine application for public information on major construction projects* • *Professionally updated messages maintained by a PR firm in-use* • *Windows Media Player software used to queue and play messages* • *Widespread usage of HAR from a local vendor, The Info Guys" in multiple districts*	HAR messages (broadcast as needed or continually)	Effective part of public outreach program for construction projects; better travel decisions.	Typical turnkey cost $1,900/ month (includes licensing, setup, maintenance, removal)

*Note: Italicized items represent updates, modifications or changes since the SPR 570 study. *Updated 2006 information is shown in italics.*

ITS Element	2006 Deployment Update	Outputs	Outcomes/Benefits	Costs
Scenic Byway Information System	• *Deployed in Kaibab National Forest on SR 67 near the North Rim of the Grand Canyon* • *2 Web Cameras* • *Byway Information Website* • *Weather Station* • *Interactive Kiosk at the Jacob Lake Visitor Center* • *Interactive Kiosk at the Kaibab Lodge*	*Weather Information, Snapshot Webcam Images, Traveler Information Kiosks*	*Promotes Visitation Provides snapshots of road conditions http://www.kaibab.info/*	*$190K Scenic Byway Grant includes 3 years of Maintenance Operated under permit to the Kaibab National Forest*
Portable Traffic Signals	• *No current usage reported*	Traffic signal indications	As flagger replacement, reduces labor costs, improves safety (more visible).	About $70,000 to purchase; rental $200 to $300/day
Commercial Vehicle Electronic Clearance (PrePass)	• *System remains active at all major ports of entry*	85% of trucks bypass during times ports are open (data from Aug. 2004)	Improve business environment by port automation; improve compliance/ enforcement; more economic delivery of goods; fuel savings; reduce truck wear and tear; improve on-time service	Equipment installation free; labor costs for creating software/database links - minimal. PrePass funded by others.
Expedited Processing at International Crossings (EPIC)	• *System actively used by MVD without transponder features* • *System expanded to cover two new FAST lanes at Nogales* • *Software enhancements under contract* • *Alternative Transponder System being deployed nationally by the Department of Homeland Security*	Average queue wait time	Improved port throughput and compliance verification; increased security, efficiency, traffic management; public access to queue wait time information	Construction costs: about $700,000; Systems integration: $275,000; Annual O&M costs $30,000.
Instrumented Truck Escape Ramps	• *Hardware updated on both ramps on SR-68* • *Satellite Communications installed at MP-1* • *Web-based interface developed*	Intrusions detected: 37/ramp/yr (data: Jan-Sep 2004)	Improved agency coordination; improved safety; improved emergency response and ramp repair time	$227,350-design/instrument two ramps; $16,200/yr/ramp for O&M

*Note: Italicized items represent updates, modifications or changes since the SPR 570 study. *Updated 2006 information is shown in italics.*

ITS Element	2006 Deployment Update	Outputs	Outcomes/Benefits	Costs
Emergency Roadside Callboxes	• *Systems remain in-place* • *No system expansion*	153/yr/callbox; calls requesting services: 18% (data from July 2003-June 2004)	Improved incident response time; identification of call location; increases public sense of safety; booster antennas increase cellular communications range	US 93: $6,845/site to install (low; other costs absorbed by concurrent project); $1,720/yr/site for O&M
Rural Nighttime Motorist Assist Patrols (MAPs)	• *US-93 MAP continues to operate*	124 assists/year (data from 2001-2003)	Public relations; quickly assess needs; relieve Department of Public Safety resources; improved incident response time/safety; accident prevention	Bid item on current US 93 project represents less than one-half percent of total project cost - $150,000 for 30 month project

*Note: Italicized items represent updates, modifications or changes since the SPR 570 study. *Updated 2006 information is shown in italics.*

2.1 DYNAMIC MESSAGE SIGNS

Permanently-mounted overhead Dynamic Message Signs (DMS) are well liked, highly visible and effective traffic management tools valued by each of the Districts. These signs are also referred to as Variable Message Signs (VMS). Every District expressed interest in having more DMS deployed within the District. A contract to purchase fiber optic signs from a French supplier recently expired. The contract has been replaced with a new DMS procurement contract which allows the state to procure signs in multiple sizes from multiple vendors. The overhead sign for freeway application will have a walk-in case, to facilitate maintenance without lane closures. Many of the Districts rely on the Traffic Operations Center (TOC) to control the signs. Some Districts (e.g., Flagstaff, Tucson) will operate the signs during working hours from the District office.

ADOT continues to expand rural DMS deployments at a rate of four to five signs per year. A contract was awarded in 2006 to CS Construction Inc. of Phoenix to install state-furnished DMS with fixed CCTV at the following locations:

- Interstate 15 at MP 8 (NB Direction)
- Interstate 15 at MP 28 (SB Direction)
- Interstate 40 at MP 124
- Interstate 17 at MP 228 (SB Direction)

The engineers' estimate for this work was $596,127. The low bid was $891,807, so the average installation cost per site on this contract is approximately $223,000. The overall cost per rural full-matrix DMS site is likely to be in the $300,000 to $350,000 range including design, the state-furnished sign, and installation, making fixed permanently-mounted DMS a relatively high-cost ITS element. The ability of the signs to provide warnings to nearly all travelers on a particular route, and possibly prevent crashes and other delays, is likely to justify continued investment in this technology.

Portable Dynamic Message signs have been universally accepted in all of the Districts as an effective work zone traffic management tool, and as a means of delivering public information. They are normally rented from construction contractors, who provide and maintain the signs for the duration of the contract period. All ADOT Districts also have portable DMS units available to assist with maintenance activities and long-term detours.

Shoulder-mounted DMS are effectively being used in the Kingman District as part of the truck ramp warning system. Shoulder-mounted DMS can be cost effective for providing real-time information on two lane roads, and for long term construction operations.

2.2 511 TRAVELER INFORMATION

Rapidly rising call volume statistics indicate significant public interest and awareness in the 511 telephone service. Call volume has grown from 314,000 calls per year in 2002 to 760,000 calls per year in 2006, with 411,000 calls through the first half of 2007. The service incorporates voice recognition technology. Despite the popularity and increasing usage of this service, two challenges were identified during the district discussions:

- Events may not be entered into the 511 system, for example, a problem or closure ahead that the traveler information system is not yet aware of. This appears to be primarily an issue of ADOT staff entering the information into the system, but it can lead to some motorist frustrations. The first example would be motorists sitting in a queue with no idea why they are stopped despite using the 511 service. The second case would be a driver approaching a closure and "demanding" to be let through because 511 indicated that the road is open.
- The voice recognition feature has not yet been perfected. The problem cited is that it does not understand voice prompts from callers. It is likely that this is due to high background noise and cellular signal quality, as many users call this service from their cars.

The Internet traveler information service www.az511.com continues to increase in popularity. The number of webpage hits has grown to more than 200 million per year (19 million per month) in comparison to 75 million in 2003.

The installation of a Department of Public Safety (DPS) computer-aided dispatch (CAD) terminal at the ADOT Traffic Operations Center has increased that facility's operator timely awareness of incidents as they occur on Arizona's roadways. The Highway Condition Reporting System (HCRS) is the underlying database for ADOT's web-based and telephone-based 511 information services. The process to transfer incidents from the CAD system into HCRS is currently done manually. Utilization of this tool has increased each year since 2003. Table 2 summarizes the number of entries into HCRS by year.

Table 2. Incident Entries into HCRS per Year

Year	# of HCRS Entries
2003	10,000
2004	20,000
2005	30,000
2006	46,000
2007 (through June)	24,000

2.3 HIGHWAY ADVISORY RADIO

The Department is using highway advisory radio (HAR) or traveler information stations (TIS) for Hoover Dam truck restriction warnings, and as part of the public information component for major construction projects. HAR furnished and maintained by the contractor has become a mainstream tool for public information during construction projects. Professionally-prepared weekly updates to the messages have been required on recent construction projects. The ADOT Communications and Community Partnerships (CCP) public and media outreach group is also a resource to prepare and update the HAR messages consistently, if so requested by the district staff.

Table 3 shows the licensed TIS users in Arizona in the authorized AM bands at 530 kHz and in the range of 1600 to 1700 KHz. Recent licensing activity shows that there is significant interest in the State for providing traveler information via radio.

Table 3. Licensed Traveler Information Stations

Agency	License #	Transmitter Site	City	County	Frequency (kHz)
Gila County	WPKL489	North Broad St.	Globe	Gila	1610
ADOT	WPPD286	I-17 MP 262	Cordes Junction	Yavapai	530
ADOT	WPPD286	I-10 MP 133	Tolleson	Maricopa	530
State of Arizona	WPQI768	Statewide	N/A	N/A	530
State of Arizona Game & Fish Dept	WPXX642	Hwy 260	Eagar	Apache	530
State of Arizona Game & Fish Dept	WPZH433	S. Lake Mary Rd.	Flagstaff	Coconino	530
ADOT	WQCY276	Mohave County	Kingman	Mohave	1610, 1640
City Of Winslow	WQDF361	I-40 Exit 233	Winslow	Coconino	1610
State of Arizona Governors Office Highway Safety	WQDL670	Delgado St	Flagstaff	Yavapai	1610
ADOT	WQEL573	Mohave County	Kingman	Mohave	1610, 1620 & 1630
City of Phoenix	WXK790	Sky Harbor Blvd	Phoenix	Maricopa	1610
Grand Canyon National Park	N/A	Desert View; Tusayan	Grand Canyon	Flagstaff	1610, 530

The quality of HAR equipment available in the marketplace varies widely, and some Districts have reported much better success with some vendors than others. The user interface for the newer HAR systems is the Windows Media Player Software, which makes HAR an easy-to-use tool. While none of the Districts have formally studied the effectiveness of HAR, it is perceived as effective and there is some interest in expanded use of the tool. Widespread radio coverage of I-40 is of interest to the Holbrook District.

2.4 ROAD WEATHER INFORMATION SYSTEMS

Nearly all of the Districts would value data supplied by road weather information systems, however only two new RWIS sites have been deployed since 2004, on SR 264 at Window Rock, and on I-40 at Two Guns. The problem has been lack of reliability of the previous field hardware deployments. Quixote Corporation is now under contract to upgrade the 16 RWIS sites, and to provide weather information services to ADOT for five years. If weather data can be obtained reliably and at a reasonable cost, some interest exists in an expansion of the number of weather stations.

The Kingman District has created an innovative Intergovernmental Agreement (IGA) with Mohave County to obtain data from its Automated Local Evaluation in Real Time (ALERT) system. The system is comprised of stream gauging sensors interconnected via a VHF radio system to collect weather data. There was only a limited awareness of County ALERT systems as a source of weather data in most of the other Districts.

The Kingman and Globe Districts reported making limited use of contracted weather forecasting services. Globe uses Accuweather and Kingman uses DTN. The other Districts use publicly available sources of weather information for winter maintenance scheduling and anti-icing treatment planning. Contracted forecasting services will be available through ADOT's Weather Information Services Contract for the next five years. The contract price is $300 per site per month.

The Safford, Tucson and Yuma Districts all expressed interest in better detection and warning for dust storms. ADOT's only dust storm detection resources, the RWIS sites at Bowie and San Simon on I-10, have not been expanded in the last two years.

2.5 MOTORIST ASSIST PATROLS

A contracted ADOT motorist assist patrol continues to operate at night on US 93 south of Kingman. This motorist assist patrol is funded through a construction project. There also are motorist assist patrols being operated on an as-available basis by DPS volunteers in the Prescott and Flagstaff Districts. The Tucson District contracts for an emergency tow service on the I-10 widening project in downtown Tucson, through the end of the project in 2010. This is a continuous operation, on call twenty-four hours a day, seven days a week. The Flagstaff District is also considering the use of an emergency tow service for the I-40 reconstruction programmed for 2010 or 2011. Most other districts also provide more informal assistance to stranded motorists in their regular maintenance operations.

2.6 REMOTE CAMERAS (CCTV)

New web cameras have been deployed at the following locations since 2004:

- SR-68 MP 1 Truck Escape Ramp
- SR-68 MP 5 Truck Escape Ramp
- SR 67 at Kaibab Lodge
- SR 67 at Jacob Lake
- Interstate 15 at MP 8
- Interstate 15 at MP 28
- Interstate 40 at MP 124
- Interstate 17 at MP 228

Additional cameras are also planned for the Tucson area, as part of the I-10 widening project. The contract specifications also call for the existing Tucson freeway management system (FMS) cameras to be kept in operation during the construction phase. This requires the cameras to be relocated; the video data stream is to be routed to an Interim Traffic Operations Center (ITOC), operated by the construction contractor. The Tucson District hopes to add FMS features and cameras on Interstate 10 from Ina Road to Tangerine Road, as the urbanized area expands northwards towards Marana. The districts would generally value additional camera images of critical roadways.

2.7 PASSIVE ACOUSTIC DETECTORS

The few rural passive acoustic traffic detectors installed as part of the old RWIS system are being removed and not replaced, since the data was not being used and the sensors were inappropriately positioned for effective traffic counting. PADs are still being used in the Phoenix FMS. There is presently no infrastructure in place on ADOT's rural roadways for real-time traffic counting and speed reduction detection. The ADOT Transportation Planning Division maintains some traffic count stations that provide basic volume counts for rural roadways for statistical purposes. There is interest in monitoring travel time, and detecting bottlenecks, on I-17 between Phoenix and Flagstaff.

2.8 LICENSE PLATE READERS

A pilot license plate reader system on SR-68 west of Kingman was removed upon completion of the design-build project in 2001, because it was intended to measure travel times during the construction phase only. The travel time data was to be used in combination with monetary incentives to ensure that the contractor conducted the construction operations with some sensitivity to the convenience of the roadway user. The system was never used as intended because Hoover Dam, the alternative route to the work zone, was closed to truck traffic in 2001. The Kingman District also reported that some motorists had privacy concerns about the use of the license plate reader system.

2.9 SPEED DETECTION AND WARNING DEVICES

One permanently-installed speed detection and warning device is in use on US-93 on the northern edge of Kingman. Use of portable speed detection and warning devices has become routine in many cities, particularly in school zones. The Prescott District reported a cooperative effort with DPS, the Yavapai County Sheriff, Prescott Police and Prescott Valley Police using portable speed warning trailers and a multi-agency speed enforcement task force to manage speeds on State Route 69. Speed warning trailers are available for rent through barricade companies.

Photo enforcement of speed was being tested into early 2007 on SR 101 in Scottsdale. This is the first application of photo enforcement on a state highway in Arizona. ADOT granted an access permit to the City, on a temporary basis. Following this pilot program, the Highway Patrol (DPS) was mandated to independently review various photo enforcement system options that may meet the state's criteria for future highway operations. A municipality has also requested an ADOT permit to do photo enforcement for speed and red light violations on SR 69 in the Prescott District. As of mid-2007, no photo enforcement permits have been issued for SR 69.

2.10 INSTRUMENTED TRUCK ESCAPE RAMPS

The Department has instrumented two truck escape ramps in the Kingman District. They are on SR 68 approaching Bullhead City, at Milepost (MP) 1 and MP 5. The system was upgraded in 2005 to provide functional warning sign control, night vision cameras, web-based user interface and e-mail alerts.

The Globe District has four truck escape ramps. They are currently not monitored, and the district has expressed mild interest in instrumenting their ramps. There are also two truck escape ramps on I-17, which do not have any such monitoring systems..

2.11 EXPEDITED PROCESSING AT INTERNATIONAL CROSSINGS

A weigh in motion system is in place at the Nogales Port of Entry. The system was expanded from two lanes to four lanes in 2006.

2.12 EMERGENCY ROADSIDE CALL BOXES

Roadside call box systems on I-19 and US-93 remain in operation, but no call boxes have been added or removed from service since 2004. Some call boxes on I-19 have been upgraded to meet Americans with disabilities Act (ADA) standards. No new ADOT call box installations are currently planned in Arizona.

The Yuma District, however, would consider the use of call boxes on I-8 and I-10, since these routes enter Arizona from California. Across the border, the State of California installs call boxes at one-mile spacing on these Interstates and some other main routes, wherever cell service is adequate.

Most other Districts would prefer to invest in improved cellular coverage for the State Highway System.

3. STAKEHOLDER FOCUS REVIEW

This chapter details the 2006-07 stakeholder needs assessment process. The project team interviewed key staff in each of ADOT's rural districts to identify specific ITS needs, resource gaps, and operational issues. This effort developed a consensus from each district on the current ITS needs, with emphasis on the originally scoped five focus areas.

Each ADOT district's Rural ITS champion was interviewed for specific regional needs. Anyone with specific insight into the district's ITS experiences and needs was also encouraged to take part. Participants in the interview process included the district engineers, regional traffic engineers, development engineers, maintenance engineers, maintenance superintendents, and the ATRC project manager and project consultant for this study. These meetings were intended to help identify ITS data, procedural, functional, infrastructure and agency needs and constraints in each of the five primary study focus areas. On-site district meetings were conducted in:

- Flagstaff
- Globe
- Holbrook
- Kingman
- Prescott
- Safford
- Tucson
- Yuma

The purpose of the interviews was for the research team to learn about each district's needs and its existing ITS deployments. The needs assessment included the five focus areas, general needs, and any additional needs. Each focus area was reviewed to gauge the level of importance and priority that each stakeholder group places on the focus areas. A secondary purpose for the interviews was to inform the districts about current ADOT activities that relate to rural ITS, including other districts' experiences with ITS deployments.

The meeting minutes recorded the district's responses to structured interview questions. A summary of needs is presented in matrix form to help identify commonalities between the districts, and to determine the primary needs. A discussion and analysis for each of the five focus areas were documented, as well as general district needs.

Each individual district's experiences and needs are summarized in this chapter, which also identifies its vision for ITS deployment. Identified ITS needs are compiled in a matrix by district. The matrix is accompanied by a discussion of needs in each of the focus areas. Specific needs for each major corridor in the State are also identified, where an ITS needs assessment for each of the primary corridors in the state is presented.

3.1 DISTRICT ITS VISION

Each of the districts has differing priorities, ITS needs, and current deployment levels. The following sections will show that there is a significant overlap among the districts' perceived needs, and their regional visions of ITS for the future. However, some needs that are unique to specific districts were also identified, as summarized below:

3.1.1 Flagstaff District

The Flagstaff District includes parts of Mohave, Coconino, and Yavapai Counties. The District's primary concerns include accurate weather forecasting, real-time traffic monitoring, coordination with other agencies on interstate closures, ITS maintenance funding, bridge deck icing, and wildlife collisions. The most important of the five project issue areas for the District are ITS maintenance and weather forecasting. The least important issue is motorist assist patrols.

The vision for the Flagstaff District is to have a fully automated communication system to alert motorists to hazardous conditions, including icy road surface conditions, low visibility conditions, rockslide events, wildlife presence, and severe weather conditions.

3.1.2 Globe District

The Globe District includes parts of Navajo, Apache, Gila, Maricopa, Pinal, Graham, and Greenlee Counties. The District's primary concerns include accurate weather forecasting, snow and ice removal, and traveler information systems. The most important issues for the District are weather information systems and ITS maintenance. The least important issue is motorist assist patrols.

The vision for the Globe District is to have more ITS technology, particularly DMSs and low cost weather information systems, if funding for capital costs and on-going maintenance are available.

3.1.3 Holbrook District

The Holbrook District includes parts of Navajo, Apache, and Coconino Counties. The District's primary concerns include traveler information systems, coordination with other agencies on interstate closures, black ice detection, snow and ice removal, accidents due to driver fatigue, and flooding. The most important of the five issues for the District is weather information systems; the least important issue is motorist assist patrols.

The vision for the Holbrook District is to have an ITS program that all of the maintenance and construction staff will buy into. The available ITS tools would become an important part of the job. The District would value tools to make the roadway safer, and to prevent fatal crashes.

3.1.4 Kingman District

The Kingman District includes parts of Mohave, Coconino, Yavapai, and La Paz Counties. The District's primary concerns include weather forecasting, snow and ice removal, flooding, and traveler information systems. The most important issues for the District are ITS maintenance and weather information systems. The least important issue is motorist assist patrols.

The vision for the Kingman District is to have accurate early warning; they stressed the need for maintainable systems. Without money to maintain it, it should not be put in.

3.1.5 Prescott District

The Prescott District includes parts of La Paz, Yavapai, Coconino, Navajo, Gila, and Maricopa Counties. The District's primary concerns include interagency communications, traveler information systems, and weather forecasting. The most important issue for the District is communication and coordination with other agencies. The least important issue is motorist assist patrols.

The vision for the Prescott District is to enhance the safety of all district corridors, specifically reducing collisions due to wildlife presence, severe weather conditions, and high speed zones. Prescott needs real-time traffic monitoring for the I-17 corridor to provide motorists with accurate roadway information.

3.1.6 Safford District

The Safford District includes parts of Greenlee, Graham, Cochise, and Pima Counties. The District's primary concerns include traveler information systems, interagency communications, coordination with other agencies on interstate closures, communications area coverage, weather forecasting, weather information systems, and flooding. The most important issues for the District are weather forecasting and maintenance. The least important issue is motorist assist patrols.

The vision for the Safford District is a better informed public, better interagency communications, a more informed workforce, a better command structure and better radio and cell phone coverage.

3.1.7 Tucson District

The Tucson District includes parts of Pinal, Pima, Maricopa, Santa Cruz, and Cochise Counties. The District's primary concerns include traveler information systems, expansion of its Freeway Management System (FMS), real-time traffic monitoring, and weather forecasting and weather information systems. The most important issue for the District is weather information systems. The least important issue is information sharing. A special concern is better monitoring of commercial vehicle operations throughout the state, and especially tracking and inspections of oversize and overweight loads.

The vision for the Tucson District is to expand the I-10 Freeway Management System to the north, and to the south. The current Tucson area FMS is on I-10 from its intersection with I-19 to Ina Road. The district would like to expand FMS northward from Ina Road. to Tangerine Road. There is significant growth in the Marana and Red Rock areas, with large residential subdivisions being constructed. FMS should also be considered on I-19.

3.1.8 Yuma District

The Yuma District includes parts of La Paz, Yuma, and Maricopa Counties. The District's primary concerns include communications with staff and other agencies, real-time traffic monitoring, traveler information systems, dust storms, and storm flooding.

The most important of the five project issues for the Yuma District is incident management. The least important issue is motorist assist patrols.

The vision for the Yuma District is to keep the roads open and to advise motorists of any hazards. They intend to focus on the roadway user's best interest and safety.

3.2 COMMON NEEDS

During the interview process, multiple needs and experiences were explored and discussed for each district. To determine commonalities between the districts, each need is categorized and identified in the matrix presented in Table 4. Needs specific to the five focus areas are grouped together. Additional needs that fall outside of the five focus areas are also included in the matrix. Cross-referencing the districts and the needs allows the most critical needs to be identified for more in-depth discussion.

Table 4. Districts Needs Matrix

Identified Need ■ – During the interview, this need was identified as a significant need □ – During the interview, this need was identified as a minor need	**Flagstaff**	**Globe**	**Holbrook**	**Kingman**	**Prescott**	**Safford**	**Tucson**	**Yuma**
Intelligent Transportation System Data Needs								
AVL for Snowplows		■		■				
Chemical Application Rate Monitors for Plows	■	■						
Snow Plow Simulator Training	■		■					
Truck Ramp Monitoring Systems		■						
ADOT Radios in all DPS Officer's Vehicles		■						
Real Time Traffic Monitoring (US 93)				■				
Real Time Traffic Monitoring (I-40)	■		■	■	■			
Real Time Traffic Monitoring (I-17)					■			
Real Time Traffic Monitoring (I-10)							■	■
Real Time Traffic Monitoring						■	■	
CCTV Monitoring	■			■	■	■		■
Procurement or Leasing of ITS with Full Maintenance & Support	■			■		■	■	
Budgetary Funding for ITS Maintenance	■		■	■	■	■	■	
Commercial Vehicle Operations Monitoring							■	
Wildlife Presence Detection	■				■			
Reduced Night Time Speeds	■							
Dam Monitoring (Flooding)	■							
Weather Information Systems Needs								
Weather Forecasting Services	■	■	■	■		■	■	■
Dust Storm Warning System						■	■	■
Low Cost Weather Sensors	■	■				■		
Additional RWIS Sites	■	■	■	■	■	■		■
Portable RWIS	■							
Flood Detection Sensors			■	■	□	■	■	■
Black Ice Detection			■					
Bridge Deck Icing Monitors	■		■	■	■	■		
Fog Warning Advisories	■							
Rock Fall Detection			■					

Identified Need ■ – During the interview, this need was identified as a significant need □ – During the interview, this need was identified as a minor need	**Flagstaff**	**Globe**	**Holbrook**	**Kingman**	**Prescott**	**Safford**	**Tucson**	**Yuma**
Traveler Information Systems Needs								
Additional DMS Locations	■	■	■		■	■	■	■
Portable DMS					■	■		■
Good DMS Maintenance Service	■	■		■	□	■	■	□
CCTV Image of DMS			■					
Multiple Agency Coordination for Traveler Information and Incident Response	■		■		■	■		■
District-Wide Communications (Radio, Cell, Satellite Coverage)					■	■		■
Improved Traveler Information			■		■		■	■
Comprehensive AZ 511 System	■		□		■	■		■
Alert System for Wide-Load CVO Permitting & Tracking							■	
Traveler Information Kiosks (Wi-Fi Hot Spots at Rest Areas)			■			■	■	
Portable Speed Display Trailers & Photo Enforcement Programs					■			
Weigh-In-Motion Systems at Ports of Entry						■		
Highway Advisory Radio Needs								
Highway Advisory Radio for Work Zones	■			■	■			
Highway Advisory Radio for Port of Entry and Rest Areas	■					■		
Highway Advisory Radio for Rock Slide Hazards	■							
Highway Advisory Radio for Traveler Information (Corridor-wide)			■			■		■
Information Sharing Needs								
Technical Publications	□	□		■		□		
ITS Arizona Conference	■		□	■				■
I-40 Corridor Coalition				■				
Training Sessions	□							
ATRC Reports & Research Programs			□			■		
Winter Maintenance Conference			■	■		■		
Roads and Streets Conference						■		
PAG Contacts							■	
Informal Information Discussions			□	□		■		
Incident Management Workshop								■
Motorist Assist Patrols Needs								
For I-40 Reconstruction through Walden Canyon	■							
For Major Construction Projects					■			
For Severe Weather Conditions			■					
Quick Clearance Law			■					

3.3 WEATHER INFORMATION SYSTEMS

Of the five focus areas from the previous project report that are being reviewed for wider rural ITS implementation, the need for weather information systems was a primary issue for all of the districts. Although the terrain and elevations vary from district to district, adverse weather conditions were targeted as a key concern for alerting motorists, deploying maintenance resources, and communicating with other agencies regarding road closures and establishing alternative routes. In the southern districts, dust storms are also critical to freeway operations. The Safford, Tucson and Yuma Districts all identified the need to advise motorists of low visibility conditions, and to seek alternative routes.

In the northern districts, snow and ice removal were constant themes in the interviews. The districts identified accurate weather forecasting as a primary concern for maintenance response, including snowplow dispatch, deicing chemical application, and freeway closures. The collective experience with the previous state RWIS infrastructure has been negative. Despite the poor performance, the need for accurate weather information is still a pressing matter and the districts are interested in obtaining this data.

The drastic range of topographies in Arizona presents a challenge to all of the districts. Across large areas of the state, and numerous interstate routes and state highways, the primary areas of concern for winter weather are typically above an elevation of 3500 feet. Areas above that level experience severe weather conditions in the form of snow, ice and freezing rain; lower areas experience dust storms and flooding conditions. The varied weather, including the unpredictable fire season, presents challenges to all of the districts.

Snowplow operations were frequently mentioned by the districts in the north. Automatic Vehicle Location technologies (AVL) were identified as a tool to improve plowing efficiency. Chemical application monitors and weather sensors mounted on the vehicles were viewed as useful tools for managing anti-icing and deicing chemical application. There is significant interest in snowplow simulator training both within ADOT and at Coconino County. Each agency has a frequent need to hire new plow vehicle operators.

3.4 ITS MAINTENANCE

ITS maintenance was a close second to weather data needs in the level of importance to the districts. Many districts described funding and resource challenges for maintaining the deployed ITS devices. Funding and staffing for these duties typically did not exist. Other districts described excellent relations with ADOT TOC for servicing DMS, but some expressed frustration with delayed responses to maintenance because of unavailable parts. This experience hasn’t deterred the common reaction of requesting that even more DMSs be constructed. Several of the districts identified favorable circumstances regarding maintenance through service agreements with third-party private companies. These outside resources provide expertise and faster response time. The exception would be the old RWIS hardware, which was effectively un-maintainable.

3.5 HIGHWAY ADVISORY RADIO

District experience with Highway Advisory Radio systems was generally favorable, except one instance where a district reported receiving low quality hardware. HAR in the rural districts is generally used for construction projects along routes undergoing major construction. The deployment is funded through the construction contract with maintenance by a third party for the duration of the contract. The districts reported favorable experiences with the vendor for several HAR sites. HAR was viewed as a means to directly communicate with motorists, and several requests were made to offer this service corridor-wide if possible.

3.6 MOTORIST ASSIST PATROLS

District experience with motorist assist patrols was sparse. This focus area was identified by almost all of the districts as being the least important of the five study areas. Several districts cited local or regional efforts by DPS to assist stranded motorists with dedicated urban freeway service patrols, volunteer rural patrols, or on-duty officers. Some tended to view it as a DPS function or service, not an ADOT function. Lack of budget and lack of time were also frequently mentioned as reasons for MAP's low priority in ADOT. Previous experience with motorist assist patrols usually related to major construction projects, where the service was funded by the project and contracted to a third party.

3.7 INFORMATION SHARING

Internal information sharing about ITS deployments and innovations was fairly limited. Responsibility for many other duties, and lack of time, were typical reasons cited for having a limited interest in learning about ITS. ADOT's ATRC research projects were viewed as a useful method to bring technology to the Districts. The effort to explore new ITS technology was typically limited to trade publications, statewide conferences, and informal discussion with other district and maintenance managers. The typical response on the information sharing focus area was that any new technologies could not be maintained with the existing staffing levels, and therefore, new information was not beneficial to explore and pursue. It was commented by some that any new devices would unquestionably be an additional strain on the already over-strained maintenance staff. The two conferences most mentioned with relevant ITS content were the annual ITS Arizona Conference and the semi-annual ADOT-LTAP Winter Maintenance Conference.

3.8 OTHER NEEDS

Several other needs outside of the five primary focus areas were frequently expressed in the district interviews. Real-time traffic monitoring of specific corridors was mentioned by almost all of the districts. Traveler information systems were also part of the discussions. Several districts requested the capability to detect changes in freeway operations and to alert motorists to changing conditions. In some cases, alternative route guidance was mentioned, to be suggested to drivers. In other cases, at least relaying the details of any delay to the motorists would help alleviate frustration, regardless of the availability or lack of practical detour routes. Traveler information kiosks were also requested in some areas to help alert motorists to anticipated driving conditions.

In regard to traffic management and traveler information systems, the districts frequently mentioned the need for inter-agency communication and inter-communication with adjacent districts. Numerous instances of freeway closures were mentioned in which the affected districts, county road departments and local agencies were not alerted to the changed condition. Traffic control in response to freeway closures would assist motorists along detour routes that are long and off the beaten path. Contacting other agencies and even maintaining communications with other ADOT employees is a challenge in some districts. Better radio and cell phone coverage was requested. The southern region identified the need to monitor commercial vehicle operations throughout the state.

3.9 CORRIDOR-SPECIFIC NEEDS: SUMMARY MAPS

During the stakeholder interviews, each District was asked to identify specific areas or locations where issues exist that could be managed through the use of ITS tools, in order to capture these locations on a map. This section should be considered as a predecessor to a deployment plan (rather than an actual deployment plan) because it focuses only on locally-expressed needs, without consideration of any of the practical concerns associated with deployment. Some examples of the issues <u>not</u> considered would be whether the deployment is feasible, or if the extent of deployment is realistic. For example, if a real-time traffic monitor is chosen for deployment on Interstate 17, it would make little sense to end the functionality at a District boundary.

Regional corridor maps are shown in Figures 1 - 6 for the following corridors:

- I-8
- I-10
- I-17
- I-19
- I-40
- US 93

The corridor-wide needs represented on the maps include real-time traffic monitoring (vehicle speeds, volumes, etc.), weather information (roadway surface temperatures, weather forecasting, precipitation type, etc.), wildlife presence detection, and HAR coverage. The location-specific needs represented on the maps include:

- Trailblazer Signs
- Traveler Information Systems
- Dynamic Message Signs
- Bridge Deck Monitoring
- Flood Detection
- Ice Detection
- CCTV Monitoring

Trailblazers include signage for detour routes that are either static or fold-down signs to alert motorists to the correct direction of travel. These way-finding signs would be used when the major corridors are closed due to severe weather or major incidents, and would help motorists stay on the desired route through rural sections of the districts.

Traveler information systems could include information kiosks at appropriate sites for updating travelers and alerting them to roadway conditions. Bridge deck monitoring, flood detection, and ice detection would initiate automated chemical deployment or advanced warning systems alerting drivers to adverse roadway conditions. DMS and CCTV monitoring would be placed at strategic locations to alert drivers to roadway and weather conditions, and to provide remote monitoring for the Department, respectively.

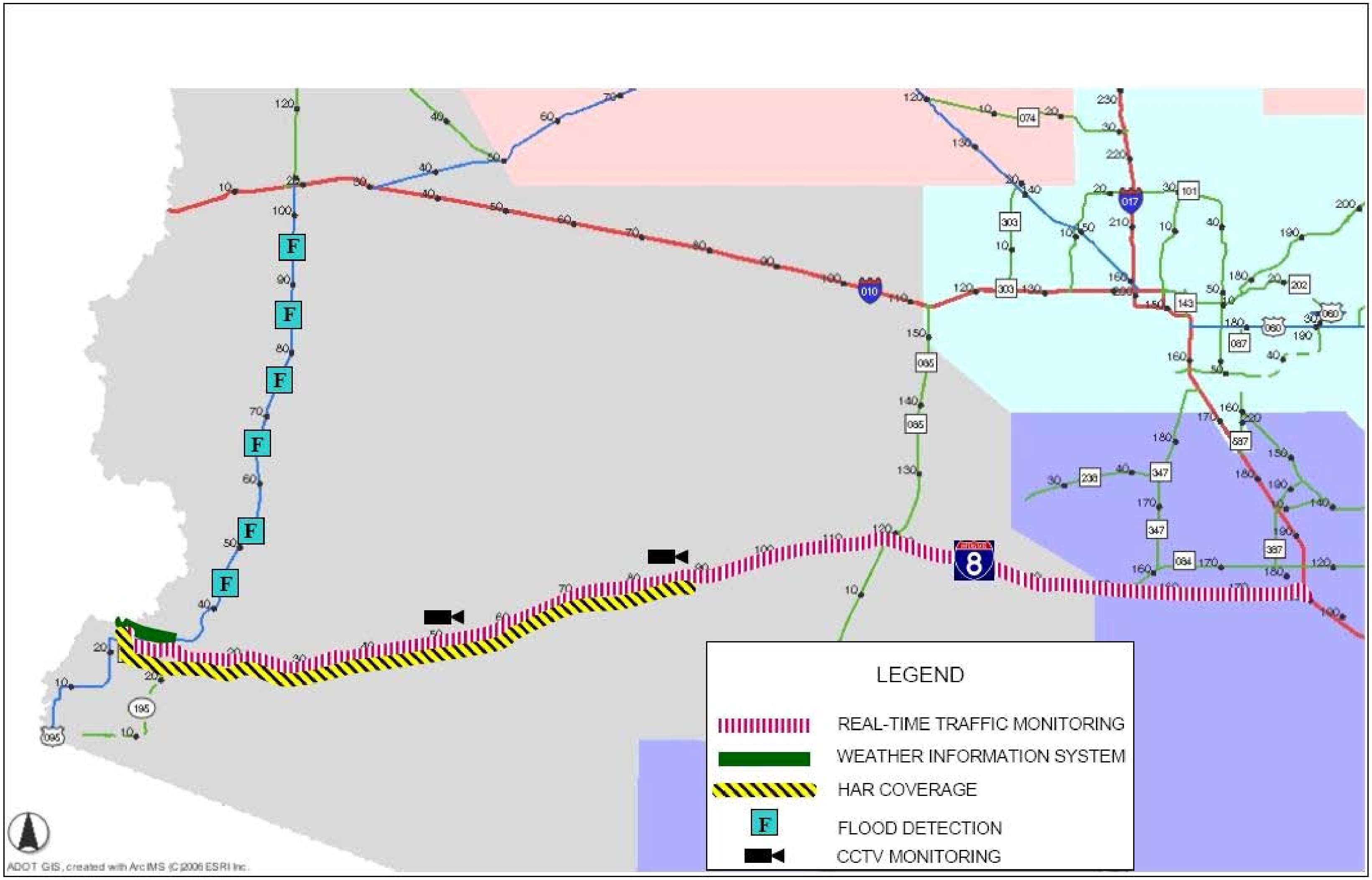


Figure 1. I-8 Corridor ITS Needs

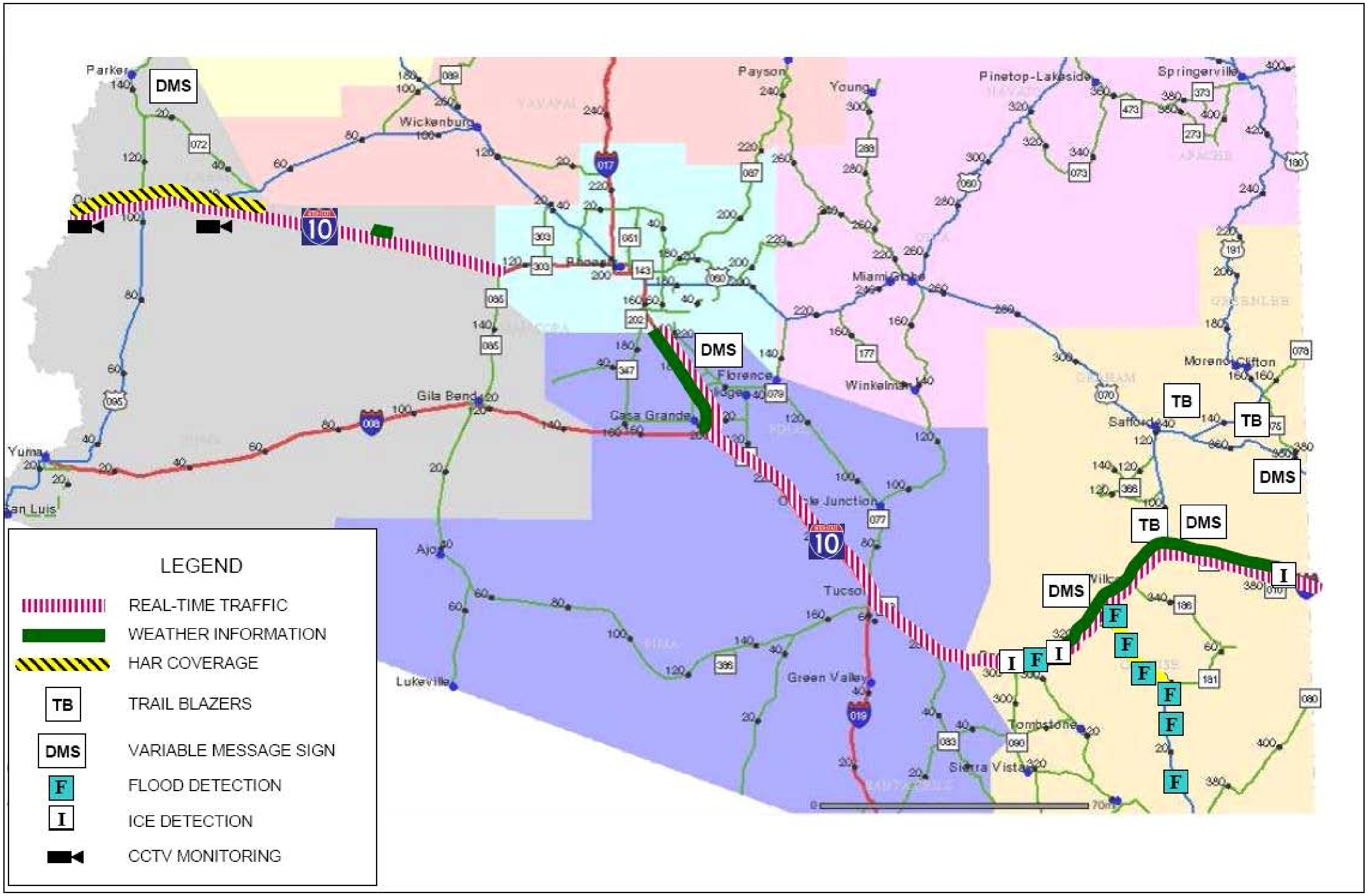


Figure 2. I-10 Corridor ITS Needs

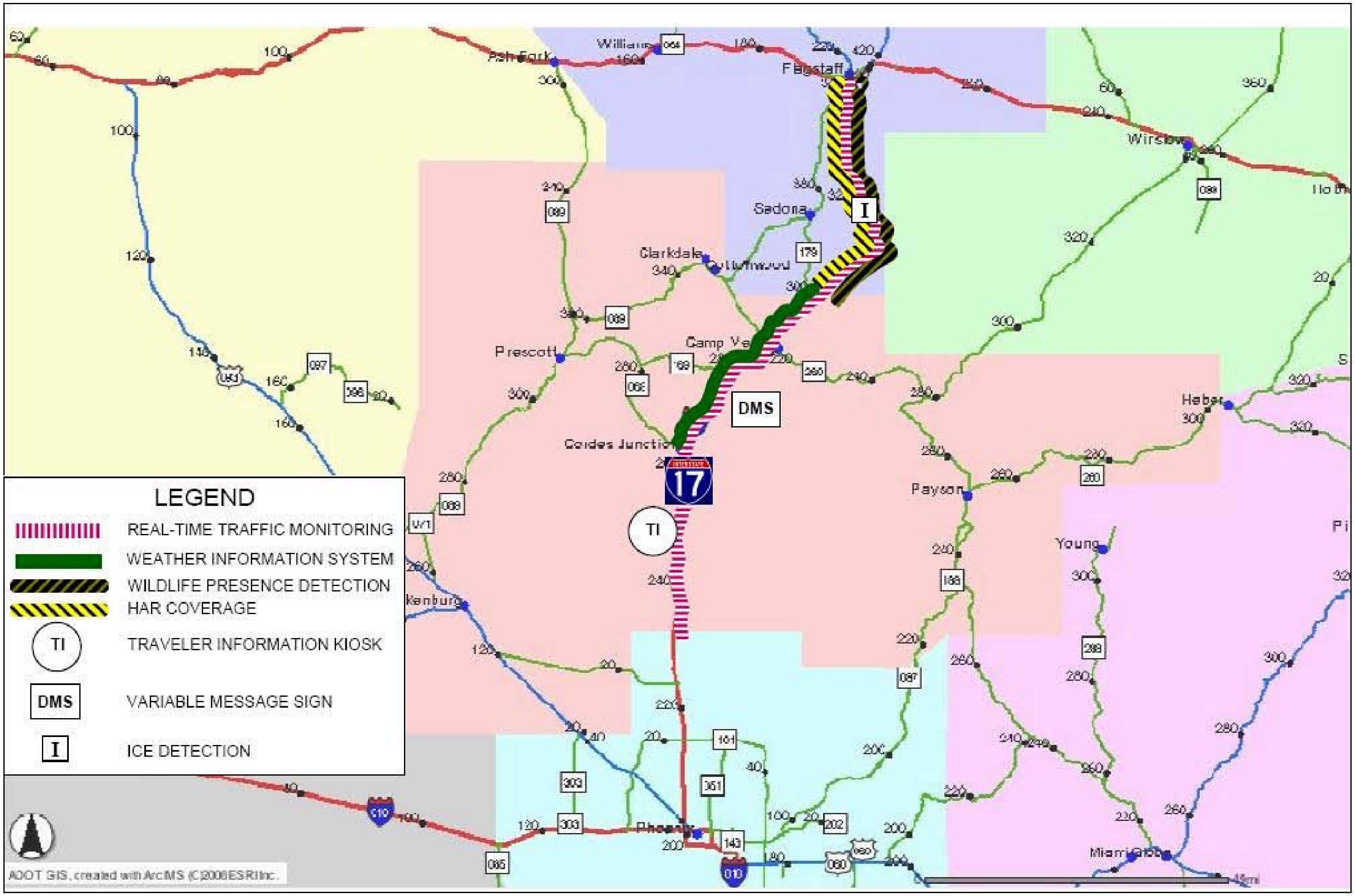


Figure 3. I-17 Corridor ITS Needs

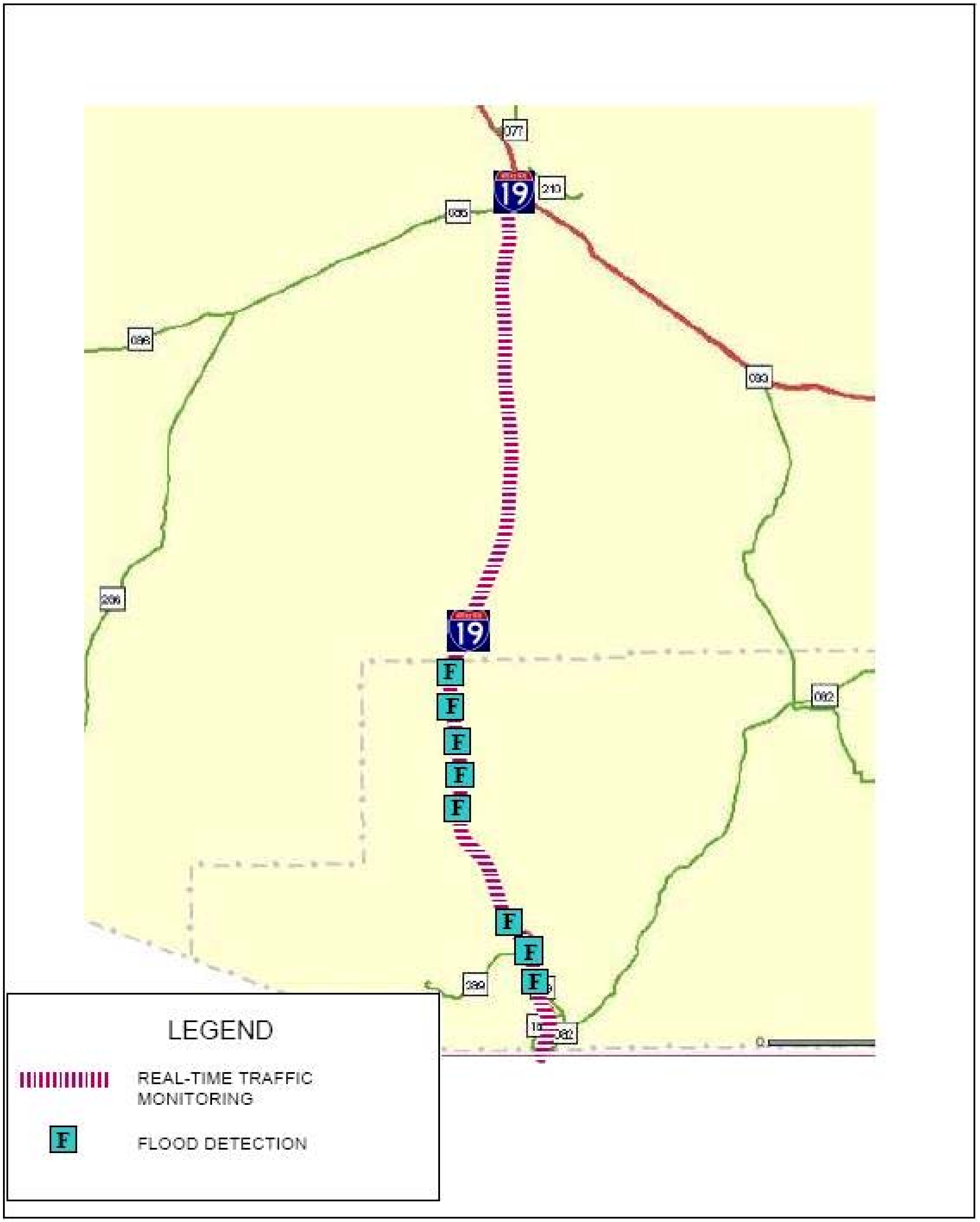


Figure 4. I-19 Corridor ITS Needs

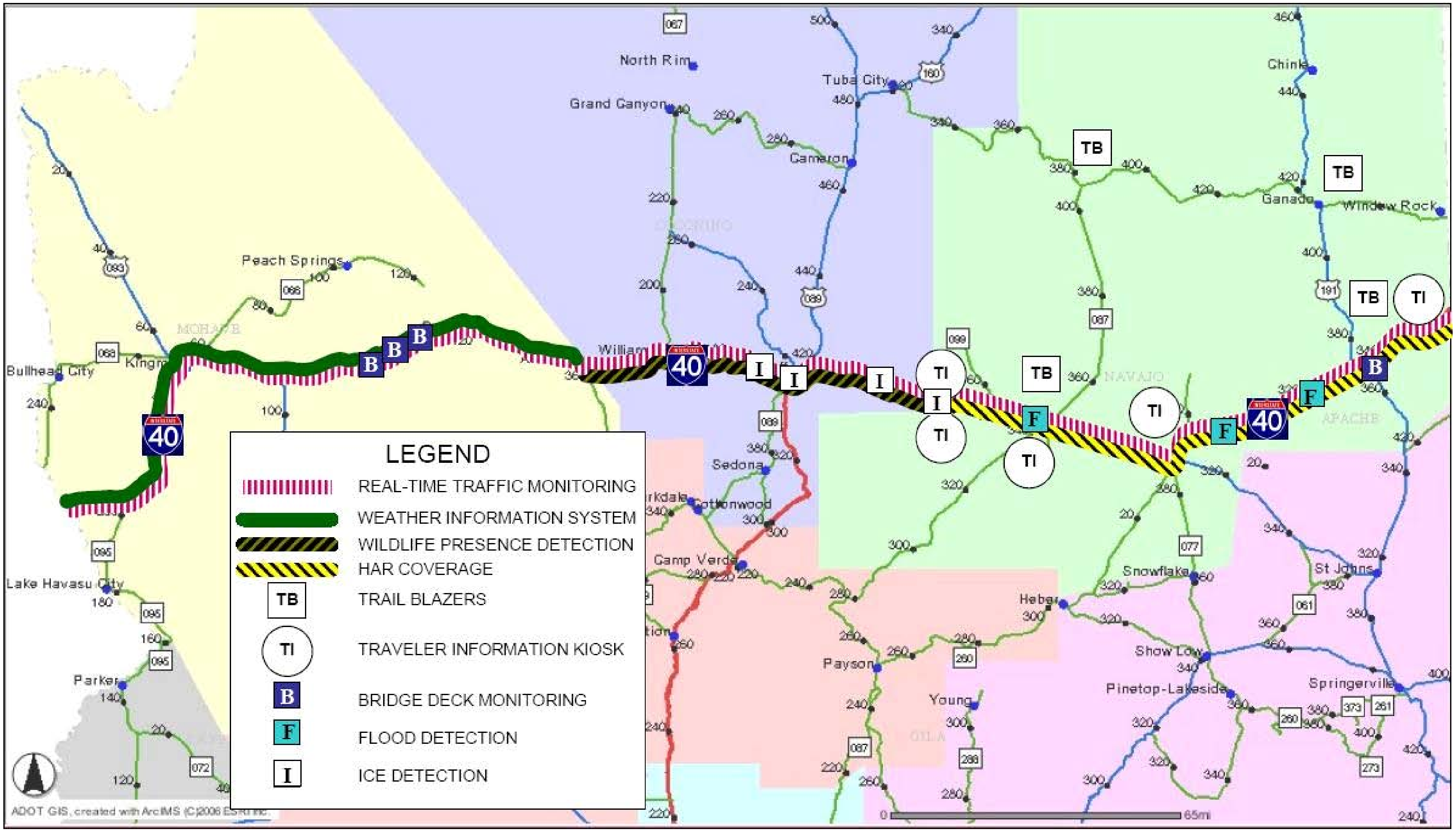


Figure 5. I-40 Corridor ITS Needs

Figure 6. US 93 Corridor ITS Needs

PART TWO – STATE OF THE PRACTICE

4. ITS MAINTENANCE STATE OF THE PRACTICE

This chapter is the first in a series that documents the information and experience collected through research conducted on current ITS deployment technologies and business practices by public agencies nationwide, as well as newly available technology from industry vendors. These five chapters compile the reviews of technology and business plans used for innovative rural ITS systems to help identify the "best practices" to effectively address the identified concerns of the Department. The emphasis is on the most promising aspects that were researched.

The research methods used to collect data and information included conducting a web-based survey of new products and innovations related to rural ITS. The primary focus areas of the research were: effective ITS maintenance and management practices and tools, weather information systems, highway advisory radio systems, motorist assist patrol fleet and program management, and innovative ITS technology transfer opportunities. Research methods and resources employed included:

- General web searches using standard search engines such as Google and Yahoo.
- Specific web searches of federal, state government and DOT websites.
- On-line searches of transportation libraries (TRB, UC Berkeley, TTI, FHWA).
- Reviews of relevant pool-fund study materials through the Enterprise, Aurora, Clarus, and TMC pool fund programs.
- Professional Society Databases (ITE and ITS America)
- Industry conference proceedings (including the National Rural ITS Conferences)
- Professional society journals (IMSA Journal, ITE Journal)
- Industry publications (Traffic Technology, ITS International)
- Vendor literature

To learn about some of the latest developments in the rural ITS field, and to develop a strong background in the underlying materials, the research team participated in the following conferences, teleconferences and meetings specifically for this project:

- National Rural ITS Conference in Big Sky, Montana, Fall 2006.
- QTT Weather and Transportation Workshop in St. Louis, Missouri, Fall 2006.
- ITS Arizona Conference, Phoenix, Arizona, Fall 2006.
- I-40 Corridor Coalition Meeting, Flagstaff, Arizona, Fall 2006.
- Teleconference with Mr. Scott Rose, President of The Infoguys.
- Teleconference with Daryl Mayhew, UDOT.

Recent relevant experience in this area of research also included the following conferences and meetings:

- Site visit to Enroute Systems, CDOT's Maintenance Contractor, 2005.
- Meeting with Frank Kinder, CDOT's ITS Maintenance Manager, 2005.
- ITE District 6 Meeting in Bozeman, Montana, 2005.
- Site visit to City of Los Angeles Special Traffic Operations Branch to discuss incident and special event management, in 2005.
- Exploratory Meeting with Caltrans District 9 for ITS on US 395, in 2005.
- Scenic Byway Coordination Meeting with the Hennepin County Department of Parks and Recreation, Minneapolis, Minnesota, in 2004.
- Round Table Discussion of ITS Maintenance at the National Rural ITS Conference in Palm Harbor, Florida, in 2003.

ITS maintenance was of primary interest to the districts during the stakeholder interview process. Many districts acknowledged funding and resource challenges for maintaining deployed ITS devices. Funding and staffing for ITS device maintenance typically did not exist at the District level outside of the Phoenix Metro area. Some common maintenance challenges that an ITS Maintenance Business Strategy should seek to overcome are:

- Sufficient funding may be available for deployment, even though ongoing maintenance costs are being neglected or underestimated.
- Maintenance response-level issues including long outages and extended times to complete repairs.
- Availability of spare parts and long lead times for spare parts orders.
- Obsolete equipment.
- Remote physical locations of field devices.
- Low quality equipment or end-of life systems.
- Lack of properly trained or qualified staff to perform maintenance operations.
- Clear delineation of maintenance responsibilities.

4.1 ITS MAINTENANCE BUSINESS PLANS

This section discusses a series of ITS Maintenance case studies based on the experiences of several DOTs. The first part of each case study describes the challenges faced by the agency; the second section describes solutions that are being implemented or explored. The rural ITS maintenance experiences of the following agencies are discussed:

- Colorado Department of Transportation
- Florida Department of Transportation
- Montana Department of Transportation
- Oregon Department of Transportation

4.1.1 Colorado Department of Transportation

The Colorado Department of Transportation began its intelligent transportation system program with a small number of devices in 1998: [4]

- 14 Variable Message Signs
- 3 Dial Up Closed Circuit Television Cameras
- 5 Highway Advisory Radios
- 22 Call Boxes

In 1998, CDOT had little or no ITS maintenance capability. Between 1998 and 2004, the Department's intelligent transportation systems grew rapidly, with a $25 million investment. Through a variety of projects and a politically savvy defense contractor turned intelligent transportation integrator, significant ITS field infrastructure was deployed. By 2004, the system had grown to include the following devices:

- 214 Variable Message Signs
- 204 Closed Circuit Television Cameras
- 19 Highway Advisory Radios
- 72 Ramp Meters
- 112 Call Boxes
- 84 Weather Stations
- 11 Weigh-in-Motion Locations
- 400+ miles of fiber & wireless communications

Rapid and massive expansion of the system without a commensurate growth in maintenance forces was the major challenge for the system. Other challenges included:

- Staffing determined by state statute must not exceed a given level of Full-Time Employees (FTEs).
- ITS Staffing level has been constant for the last 7 years.
- Currently limited in the ability to hire new staff.
- Insufficient vehicle resources.
- ITS maintenance was not a priority for the traffic signal technicians.

CDOT recognized the investment in the technology and established performance standards for the system. These systems goals include:

- Maintain high device reliability.
- Maintain 90% plus up-time.
- Maintain high visibility devices to foster positive public image and perception.
- Effectively operate the devices for their intended purpose.
- Maintain high levels of customer satisfaction for highway users and traveler information service users.

CDOT then took an asset-management–based approach and established a maintenance asset tracking system to document the investment in ITS devices and their current functional state. This tool was used to garner the support of senior management to enable the Department to engage in contracting for ITS maintenance. As a result of these efforts, a local start-up contractor was chosen to provide maintenance services. The contractor, Enroute Systems, currently provides high levels of service to CDOT through a dedicated full-time staff exclusively serving the ITS maintenance needs of the Department. The firm is co-located in CDOT facilities in Lakewood, Colorado. Staff provided includes:

- 1 Working Manager
- 1 Maintenance Coordinator
- 6 Technicians
- 1.5 Network Managers

The firm functions as an extension of the Department's staff and assists with a variety of duties such as troubleshooting communication links, optical time domain reflectometer (OTDR) testing of fiber optic cable and deploying portable DMS.

4.1.2 Florida Department of Transportation

Florida DOT created the ITS office in 2000 to facilitate deployment of ITS through a centralized resource in the department.[5] In 2003, the office reported that it is focused on deployment instead of maintenance and operational issues.

While developing the plan, the department developed cost estimates for maintenance and operations. The estimated cost over 10 years was $54 million for new ITS (not the cost of existing systems such as I-10 in Jacksonville, I-4 near Orlando, and southeastern Florida). Cost estimates were based on Federal guidelines and existing maintenance costs where available. Obviously, maintenance is a big concern for the department. Since the system is relatively young, not all maintenance challenges have been solved.

Florida DOT developed a "cost-feasible" ten-year ITS plan with a total $500 million budget, which supplements $200 million in committed district funds. The plan covers both urban and rural areas through 2012, though urban areas receive the bulk of the funding in the plan. The plan doesn't address maintenance or operational issues.

In 2005, the Department created a Change Management Board with the stated purpose of overseeing and managing ITS deployments in Florida. The specific emphasis is on implementing needed changes in a deliberate, controlled manner that takes into account the impact on regional and statewide systems. The board includes members from multiple FDOT districts, the state ITS office, local universities and a consultant to provide program support. Creation of this board is an important step in managing the lifecycle of ITS deployment.

Some of the ITS maintenance challenges reported by the Florida DOT include:

- ITS is *"the new kid on the block"* as opposed to building and maintaining roads.
- Roads don't have the immediate, 24-hour maintenance issues that ITS projects do, so it is hard to get senior management to recognize the urgent resource needs for ITS maintenance.
- Florida DOT still has a predominantly asphalt-and-concrete mindset.
- Maintenance problems should wane once that mindset changes, although there will always be funding questions.

Potential solutions and current steps by FDOT to better manage ITS maintenance are:

- Working group meetings and teleconferences between districts and state occur frequently to discuss ITS deployment and maintenance issues.
- Maintenance is frequently brought up by districts, since they will need to take care of maintenance.
- Maintenance funding is done largely by formula, based on unit costs by device. One problem is that there are only four categories of unit costs, so the system of allocating funds needs to be improved.
- With more ITS projects in the state, it will become more mainstreamed, so managers will think more of necessity to provide maintenance.
- Training and education is crucial for ITS maintenance. An important piece of this is educating managers to change the concrete/asphalt mentality, so that they're more sensitive to need for resources to maintain ITS. Greater support from management about ITS maintenance will help.
- Initial maintenance during the early stages of deployment can often be handled through the installation contractor as a warranty or support issue.
- Florida DOT is moving away from in-house maintenance, due to state budgetary problems.
- Maintenance lends itself well to outsourcing due to manpower issues, but there is still a need to train personnel so they can effectively oversee maintenance projects, and to manage maintenance contracts.

4.1.3 Montana Department of Transportation

The Montana DOT[6] has a relatively small rural ITS deployment, but system expansion is taking place with several new devices added each year. Deployment to date includes:

- Seven permanent Dynamic Message Signs (DMS).
- Five Highway Advisory Radio (HAR) stations.
- The 511 road condition information system.
- 60 road weather information station (RWIS) sites, 12 of which have cameras.

Some of the challenges faced by the Montana Department of Transportation include:

- Coordination among three divisions within the Department responsible for deployment, telecommunications and maintenance can take significant effort.
- The Department also does not have a long-term strategy for ITS maintenance.
- The lack of a long-term plan makes it difficult to plan training for workers or hire contractors.
- An FTE limitation prevents the Department from hiring staff to be responsible for ITS maintenance.
- In remote areas, there are no qualified contractors to perform maintenance.

In Montana, maintenance and deployment of ITS devices are woven into one funding element, but managed through three separate divisions in the department over the lifecycle of the device. The Engineering section is responsible for design and deployment. The Maintenance section is responsible for device maintenance. The Information Services section is responsible for communications connections.

Montana DOT is investing resources in training for its maintenance staff to help troubleshoot devices. When the equipment fault cannot be solved locally, the suspect equipment is packed and shipped to the vendor for depot repair.

In the future, Montana DOT is looking more toward contracting as the number and types of devices in the field increases and overwhelms the capacity of the existing staff. Montana is looking towards the Oregon DOT model to make good decisions on who maintains what devices, and how.

4.1.4 Oregon Department of Transportation

As part of its mission to provide safe and effective transportation systems that support economic opportunity and livable communities for Oregonians, the Oregon Department of Transportation (ODOT) is increasingly relying on the use of intelligent transportation systems.[7] ODOT developed a statewide ITS Strategic Plan outlining the deployment of ITS devices from 1997 through 2017 to improve the safety and efficiency of the transportation system. In 1999, ODOT recognized that for the ITS devices to meet the needs of the Department and the traveling public, proper maintenance is essential. This realization led to the development of a Statewide ITS Maintenance Plan for ODOT by the Western Transportation Institute at Montana State University in Bozeman.

This plan was intended to be a long term plan that addresses both technical and institutional issues. Activities involved in plan development included stakeholder outreach, a literature review, development of a maintenance model, establishment of priority guidelines, definition of a preventative maintenance program, resource analysis, and short, mid and long term maintenance budgets.

ITS maintenance challenges facing the Oregon Department of Transportation include:

- Traditional channels within ODOT for maintenance of other systems are not adequately handling ITS maintenance needs.
- Electricians are the first line responders for problems with ITS devices, but are only trained in the areas of lighting and traffic signals. The IT staff maintaining the computers in the offices is not familiar with specific ITS applications.
- Inadequate staffing levels exist for current ITS deployment; ODOT stakeholders perceive the Department to be moderately or severely understaffed in this area. Devices have been added to the regions without staff to maintain them.
- Maintenance has been reactive, by "putting out fires," and preventative maintenance is de-emphasized.
- Conflicting staff priorities.
- Ambiguous responsibilities.
- Inadequate training.
- Poor or non-existent tracking systems.
- Non-standardized devices.

The Oregon solution began by recognizing the need for a long term ITS maintenance plan developed by engineering and research staff with significant stakeholder input.

The plan recognized the need to have a maintenance model, which the study defined as a method for logging, tracking and processing service requests and repairs through the organization so that maintenance is done efficiently and effectively.

Based on stakeholder input, Oregon DOT chose a two-tiered maintenance model with differing procedures for mainstream technologies and newer, limited deployment or emerging technologies.

The maintenance program established an ITS maintenance coordinator, whose primary role is to be a single point of contact to log and track maintenance activities. The model uses district and regional maintenance staff to perform maintenance on ITS field devices, and information services staff to perform maintenance on back-end computer support and communications links. At the discretion of the support coordinator, vendor and contractor support can be used to supplement state maintenance forces.

The ODOT team elected to prioritize maintenance of ITS devices based on how mission critical they are, rather than by the type of technology. Priority guidelines are based on the following criteria:

1. Fulfilling legal mandates.
2. Addressing safety hazards.
3. Deploying critical field devices that provide and promote safety.
4. Establishing communications links that provide transfer of data from field devices to a centralized location.

5. Establishing information dissemination tools for motorists, beginning first where traveler benefit is maximized
6. Restoring all other devices with emphasis on devices that have the greatest visibility to the public.

The maintenance plan included a resource analysis that examined an inventory of current and future devices and estimated the amount of time per device needed for maintenance. The plan indicated that the currently available maintenance staff consists of four to six FTEs, and that upon build-out of the strategic plan, up to 50 maintenance staff would be required, leaving a gap of more than 40 unfilled positions.

Contracting of maintenance duties was identified as a tool for fulfilling the maintenance gap. The plan recommended that contracting should be targeted towards activities where response time was not critical, where the number of deployed devices is fairly extensive, and where clear lines of responsibility between contractors and ODOT can be defined. Devices for which maintenance contracting was recommended included:

- Weigh-in-Motion systems.
- Kiosks.
- Preventative maintenance for CCTV.
- Preventative maintenance for DMS.
- RWIS field units / Environmental Sensing Stations.
- Travel time estimation systems.
- AVL in-vehicle equipment.
- Maintenance of portable DMS.
- Fiber optic communications.

ODOT uses maintenance contracting to expedite certain maintenance services; they report that in-house capability is desired for mission-critical, safety-oriented business such as traffic signal and lighting maintenance. Whenever expedited response time is required, the ODOT stakeholders hesitate to use contractors. ODOT views the use of maintenance contractors for a short term supplement to its staff as a viable stop-gap measure. This would suggest that some members of the ODOT maintenance team still view maintenance as primarily an in-house function.

ODOT believes that in many rural areas, maintenance contractors with the requisite skill will not be available or that companies will demand a premium fee to maintain rural ITS devices due to the travel times involved.

ODOT has utilized maintenance contracting as a result of legislatively mandated FTE caps. The number of employees in many DOTs, including Oregon's, is legislatively capped, thereby limiting DOTs' ability to hire employees. Furthermore some DOTs and law enforcement agencies are challenged in filling available positions with qualified technical staff in the electronics field because a significant gap exists between public sector and private sector wages. As a result, many well-qualified individuals choose employment in the private sector, rather than the public sector.

Retention of staff can be difficult in a high-tech environment, but there are ways to improve retention, such as providing opportunities for advanced training, allowing travel to technical conferences and workshops, and other non-salary-related perquisites for agency maintenance staff.

It should be noted that many municipalities hold a differing perspective in areas where there are established signal maintenance contractors, such as California, Colorado and Florida. For example, Republic Electric Company reports having more than 180 public agency clients for whom they perform traffic signal maintenance, lighting maintenance or ITS maintenance. WL Contractors of Arvada, CO reports operating a regional Traffic Operations Center which monitors traffic signal operations for a number of cities in the Denver area, who chose to use WL's traffic signal maintenance and timing services.

ADOT at one point employed maintenance contractors with limited scopes as a stopgap measure before hiring internal maintenance staff for the Phoenix FMS. Due to the limited scope, the contractor was perceived as having responsibility to repair the system, but the contractor did not have the authority to make the required repairs, such as pulling electrical conductors or replacing knocked down cabinets.

4.2 ITS MAINTENANCE TECHNOLOGY SURVEY

ITS maintenance is the primary focus area identified by the ADOT districts as having the most importance and highest priority. Nearly all of the districts clearly expressed a wide range of the challenges for maintaining the deployed ITS devices, and concerns about maintenance and service for future installation of ITS devices. Some districts described excellent relations with ADOT's TOC for servicing of Dynamic Message Signs. However, some expressed frustration with delayed responses to maintenance requests for a significant variety of reasons, including insufficient parts availability, lack of vendor response, and lack of in-house expertise.

The expressed concerns and issues for ITS maintenance include:

- Maintenance funding: typically, estimated upfront costs of the devices are being considered; however, the ongoing maintenance costs are being neglected or underestimated.
- Maintenance response level: only partial needs are being covered in response to maintenance requests.
- Remote monitoring of devices and reporting of device status is inconsistent.
- Insufficient parts supply on site: some basic parts can be ordered in advance and stored locally to be available to any District on an as-needed basis.
- Unacceptable parts delivery delays after replacement or repairs are requested.
- Shortage of trained and experienced ITS maintenance personnel.

- Upgrades and updates of the hardware are unavailable.
- No designated technician for individual devices.
- Remoteness of the device locations.

There are two types of conceptual maintenance for ITS devices:

Responsive Maintenance is the repair or replacement of failed equipment and its restoration to safe, normal operation. Typically unscheduled, this maintenance is performed in response to an unexpected failure or damage. This category refers to operations that are initiated by a fault or trouble report. The report can come either from a person or from software that is monitoring parts of the system. Most general faults fall into the responsive maintenance category. Depending on the severity of the failure, some malfunctions can require days or weeks to repair.

Preventive maintenance: Also called "routine" maintenance, it is the activity performed at regularly scheduled intervals for the upkeep of equipment and to keep the systems operating. It includes checking, testing and inspecting, recordkeeping, cleaning, and periodic replacement when called for in the preventive maintenance schedule. Preventive maintenance includes basic functions, such as cleaning camera housings and the front of DMSs. In some cases, preventive maintenance requires sophisticated technology, such as optical testing equipment to ensure that the fiber-optic in the communications system is operating within acceptable parameters. Preventive maintenance is initiated on a schedule, but resource limitations might eliminate preventive maintenance altogether.

4.2.1 Maintenance Management Software

ITS maintenance concerns can be addressed through a variety of technologies, including: AVL, Mobile Data Collection, System Monitoring, Network Management, and device-specific automated monitoring. Other concerns are more operation-oriented. This section reviews technological maintenance options available for ITS devices.

Due to the cost of ITS deployment, a method of assessing technologies' functionalities and operational statuses can alert the agency of under-performing devices to help facilitate maintenance dispatch. By cataloging maintenance efforts, maintenance can be performed on a consistent basis. ITS maintenance activities that are consistent are considered under the preventive maintenance category. Activities that support life-cycle maintenance requirements can be defined as:

- Risk management: examine system failures and causes of such failures to determine risk of obsolescence and failure to meet agency expectations.
- Configuration management (traceability): adjust maintenance concepts and requirements to maintain system performance measures, documentation of system modifications, and repair history for long-term tracking of system reliability measures.

- Validation and verification: in addition to acceptance testing, periodically conduct a validation of maintenance concepts and requirements and adjust to any changes in operational concepts or functional requirements.
- Performance metrics and monitoring: key performance indicators provide the tools needed for technical management of the maintenance program and allow the optimization and cost-effective allocation of resources.

In some cases the product life-cycle may outlive advances in technology, therefore, expected maintenance can be circumvented through implementing new devices and either removing the out-dated equipment or abandoning it in-place. Decisions can be expedited with maintenance management software that uses the above documentation techniques.

The challenges of Rural ITS Maintenance include:

- Very high contracting expense.
- Long distances between field devices and maintenance offices.
- Specialized training requirements.
- Limited system redundancy.
- Limited research to date on Rural ITS Maintenance.

One of the recognized solutions for ITS maintenance problems is to be able to estimate device reliability, maintainability, and expected device life-cycle. A management program can facilitate these solutions. The ranges of functions that ITS maintenance management software can perform include:

- Maintaining equipment inventories across warehouses, shops, and sites.
- Recording trouble calls and repairs for equipment in the maintenance system.
- Recording technician information as to trouble calls and equipment repairs.
- Accessing logged information on equipment movement and repairs made.
- Generating reports to show reliability metrics on equipment in the system.
- Transferring data from a bar-code scanner into the maintenance database tables.
- Managing all information and making corrections where appropriate.

Such software applications provide a series of screens that allow the operator to enter and view the status of trouble calls, and to view which ones are currently open. By using the repair data, comparisons can be made between equipment types, such as whether one camera manufacturer requires more repairs than another. This is an example of configuration management (CM).[8] CM is defined as a process for establishing and maintaining consistency of a product's performance, functional and physical attributes throughout the product's design, implementation, operations, and maintenance lifespan.

The more complex a system becomes, the greater the range of variables that impact system performance. With more variables, the potential for permutations and variations on possible configurations grows exponentially. Without a rigorous configuration management process facilitated by maintenance management software that documents all changes and modifications to the system, it is nearly impossible to diagnose what changes may have caused a system malfunction.

These applications provide location information for users. As systems grow, the overall number of devices that must be maintained can become quite large. When the number of deployed devices is significant, monitoring their location at all times is a challenge. Devices move for a variety of reasons. The site can be abandoned, and devices can disappear as part of reconstruction or maintenance activities. Equipment often gets moved as repairs are made. In some cases, components of old equipment are used to repair other devices. Knowing where everything is becomes a problem that can be addressed by some combination of inventory control software.

4.2.2 Dynamic Message Sign Maintenance

Dynamic Message Signs (DMSs) were identified in the district meetings as key tools for alerting motorists to changing roadway conditions. These signs are used for advising travelers en-route of upcoming or existing events and conditions on the roadway. The intent is to increase safety and prepare travelers for road conditions ahead, or notify travelers that certain events will be happening in the near future.

DMSs use a large lighted display to provide text and symbol messages. The text the signs display can be programmed from a remote location using a wireless transmitter or a phone line and modem. DMS can have either a permanent or portable installation.

Usually DMSs are mounted as overhead signs or on overpasses and are hard-wired with a power supply and telephone line. These are used more for incident management, since traffic conditions can change by the minute. Permanent installations can be used as part of a warning system of any kind (fog, snow, dust, flood, rocks, animal presence, etc).

Signs that are in disrepair are a primary concern, which is especially frustrating for motorists. If a DMS is dark while a motorist sits stalled in traffic congestion, his or her stress from the delay is compounded by the uncertainty of the incident. The key components for successful DMS maintenance are good diagnostic tools, easy access to the components, logical architecture of the device, compatibility of the components, and availability of replacement parts.

Typically, device monitoring systems are built into the sign hardware and sign control software. Some compatibility between signs of different manufacturers and third party vendor control systems can be achieved through application of the NTCIP protocol for DMS. Some of the key diagnostic and maintenance features include:

- Ability to monitor and diagnose all systems from a front panel menu.
- Real-time diagnostics for pixels, power systems, and fans.
- Ability to monitor temperature, light, door, other in-sign sensors.
- Remote controller reset capability.
- Event logging capability.

- Reserve power that allows controller and internal modem to operate during brief power outages.
- Real-time message monitor in WYSIWYG (*what you see is what you get*) format.
- Ability to send notification of malfunctioning components.

4.2.3 Automatic Vehicle Location Systems

The ability to monitor the vehicles in a fleet can expedite deployment and maximize resources. During the winter season, ADOT is responsible for deploying snowplows to respond to roadway conditions. Being able to track the vehicles in the snowplow fleet can help ADOT determine how to apply available resources, and redirect resources to important areas, in an effort to boost operational efficiency. Fleet tracking can be accomplished with Automatic Vehicle Location (AVL) systems. This technology has been successfully implemented by a wide variety of industries including commercial trucking, DOT maintenance fleets, and mass transit systems throughout the country. The applications for highway maintenance are very robust, and have been shown to increase the efficiency, utilization, and safety of the typical maintenance fleet.

Through the use of satellite communications and mapping software, the agency can track individual vehicles with AVL across a region. Based on updated information and data integration, the system users can determine where individual units are located, how much anti-icing material is available, how long the drivers have been deployed and finally which units are most appropriate to be redeployed. This information can be displayed through a web browser from a remote location, saving the Department time and resources and reduces operator work hours to minimize expenses.

This technology is designed to maximize snowplow operations while reducing applied resources (material, chemical, and man-hours). Each plow is fitted with a wireless modem and mobile data terminal. The wireless modem allows a wide area network (WAN) connection with the “Snowplow” server through the Cellular network (or satellite equivalent). The mobile data terminal is equipped with a Global Positioning System receiver which transmits location data using a wireless modem; the unit receives its geographical location data from GPS satellites. This data is then delivered to the “Snowplow” servers, either in a real-time transmission service or in a data storage/data dump service. The servers perform data manipulation functions and identify the plow location on the client application’s mapping interface.

A typical client/server application includes three servers. The first writes and computes the incoming vehicle coordinates to a database. The second server retrieves computed data and generates maps. The third server populates the maps for user display of location status for the currently-deployed vehicles. This allows the agency to track snowplow movement and snow removal progress. All three work together through the Snowplow Tracking Client/Server software, and update the operational status through a browser.

The functionality of AVL includes:

- Statistical Tracking.
- Vehicle Location.
- Vehicle Logging/Playback.
- Inclusion/Exclusion Zone Definition.
- Vehicle Symbology Configuration.
- Incorporation of other Datasets (for instance mobile data collection).
- Web Site Capture.

Statistical tracking functionality includes the ability to capture variables such as speed, direction/vector, geographic location, and the time of day. The system has the ability to summarize all of the data derived from the multiple functions into a database on a per-vehicle basis during specific time intervals. Vehicle location is the foundation of the concept, allowing the system administrators to maximize operational efficiency.

An important part of the AVL tracking technology is the ability to replay plow location information. Vehicle location data (speed, direction, time, location) can be captured in a log file for analysis and crew training. The client/server application also allows the user to incorporate other datasets and data layers for comprehensive analysis. The allowed formats include ADC Raster Maps or Digital Ortho Photography, GeoMedia Access Databases, ESRI shapefiles, and Oracle Spatial Data.

Some of the benefits of an AVL system include:

- Long term cost savings through effectiveness of equipment use and mobility.
- Increase in service to the public while decreasing call volume to the crews.
- Precise real time vehicle tracking.
- Easy dispatch and communication with vehicle operators.
- Increased safety of maintenance operations for all roadway users, including maintenance vehicle drivers.
- Flexibility that allows dispatchers to expedite immediate changes to the job assignments and maintenance routes based upon real-time monitoring.
- Easy operator-system interface.
- Accurate and efficient task scheduling with updated availability of vehicle distribution in the area.
- Real-time feedback from the maintenance vehicle on the status of the tasks.
- Full integration with the emergency response communication network and fleet dispatch and operations systems.
- Monitoring of maintenance vehicle mechanical and efficiency status.
- Playback capabilities with the goal of improving operational performance.
- Expedited response to approaching storms.
- Fuel economy savings due to real-time monitoring and efficient route scheduling.
- Ability to make the entire snow removal maintenance process visible for the public on the World Wide Web (Map server, public access server).

Some of the challenges for AVL include:

- High capital costs.
- Presence of additional equipment and related up-keep costs.
- Additional driver training.
- Enabling real-time communications for data transmission.
- Issues for fleet operators about privacy concerns resulting from monitoring.

In many cases the three systems working in conjunction (AVL, Automated Fleet Dispatch and Mobile Data Collection) are offered by a single vendor as an integrated package. This software can perform multiple operations and assignments while continuing to serve the designated functions.

ADOT did test a cellular-based AVL system in the Flagstaff area in two winter seasons from 2000 to 2002.[9] Two mobile AVL units were evaluated; one unit was hard-wired into a snowplow and the other was a portable unit tested in several different vehicles. The system test was a general disappointment, as results were hampered by poor cellular coverage and limited system capacity, as well as phone-line and modem problems, and training issues. The experience highlighted the limitations at that time of a typical cellular-based system for maintenance fleet operations in mountainous rural Arizona.

4.2.4 Mobile Data Collection

Mobile Data Collection Systems are installed in maintenance vehicles to passively record information while the operator performs maintenance or other duties and services. Passive automated data collection does not require intense operator input; collected data is delivered automatically via wireless communications to the main server and stored in a database. Most common Mobile Data Collection Systems utilize technology that collects data, processes the data into user-friendly information and transmits the information to a centralized location. By adding software, a Mobile Data Collection System-equipped vehicle will also be capable of receiving a particular request for data from dispatch via wireless bi-directional modem.

A typical Mobile Data Collection System requires in-vehicle equipment including:

- Operator input sensors (any laptop, PDA, on-board computer or navigation system, cell phone).
- Wireless modem.
- GPS transceiver.
- Antenna system.
- Vehicle-mounted display in conjunction with onboard/mobile control module (permanently installed in the vehicle, or optionally by laptop or PDA).

Typical sensors mounted on the vehicles include:

- Tilt sensor on road grader or snow plow.
- Inclinometer, hydraulic pressure switch.

- Friction meter.
- Weather data sensors for temperature, atmospheric pressure, humidity, wind.
- Road surface temperature.
- Onboard video cameras.

There are three levels of driver/operator involvement in the process of mobile data collection depending on the level of input and interaction:

- *Passive level*: All collection, receiving and transmission, task assignments, coordination, data processing, data storage, etc., is controlled by dispatch operations. The only needed active input from the driver is vehicle navigation and primary operations.
- *Active level*: Almost the entire process of data collection and processing is performed by the driver/operator. Even though most parameters and routines have been pre-set by the management center, the driver can make all required changes according to expected road conditions, scope of work, on-site requirements and vehicle condition.
- *Combination level*: The driver can control some functions, such as turning on and off particular sensors, and can assist data processing and transmission, and coordinate with dispatch as to the scope of tasks. However, most parameters need to be pre-set by the management center.

It is up to an agency to decide what level of driver input is applicable. The capabilities are pre-determined based on hardware and software installed on the vehicle, communication capabilities of the area, and the individual driver's credentials and responsibilities.

Some of the benefits of Mobile Data Collection Systems include:

- Wireless communication devices can be used for multiple purposes, including snowplow operations, dispatch, and mobile data collection, at no extra cost.
- Collecting data while also performing other tasks and duties will save operator time and effort. Material monitoring can be automatic for both the driver and the dispatcher, without additional manual driver efforts.
- No extra vehicles are needed, as all data-collecting equipment can be added to the vehicles performing other duties.
- Mobile data collection can be performed in different areas of the district depending upon needs and requirements, whereas static data collection systems can only monitor a single specific location. Thus, more areas can be accessed and covered than with permanent data collection devices.
- Instant response: collected data can be immediately processed and used for ongoing maintenance. Data collected by operating snowplows can be essential for real-time coordination of efforts based on type and amount of material used for road treatments, priorities, and the need for more or fewer vehicles in use.

- Mobile data collection can be performed by a wide variety of vehicles, including: maintenance trucks (snowplows, graders), patrol vehicles, construction/ inspection vehicles, pilot cars, tow trucks, emergency vehicles, and transit.
- As an option, collected data can be filtered in the field by a vehicle-mounted processor prior to sending the raw data to the operations control center, so as to expedite processing.
- Long term substantial financial benefits are a result of high efficiency of single vehicle operations, leading to fleet reduction.
- Compatibility and integration options are offered, with automated fleet dispatch and mobile data collection tools, hardware and software.
- Detection and monitoring capabilities include chemical formula, amount applied, rate, and available supply status of the roadway treatment materials.
- Reduced driver input or effort is required for the chemical deployment operations.
- Can be integrated with mobile data collection systems on maintenance vehicles to enable cost sharing between AVL, fleet dispatch and data collection systems.

Some of the anticipated challenges for use of Mobile Data Collection Systems include:

- High initial costs are required to implement the system. However, integration with other systems such as AVL-GPS can help to reduce capital costs.
- There are significant data processing and sorting requirements to eliminate needless data, while preserving relevant, useful data.
- There must be consistent data outputs between the various sources, or else steps incorporating the data into one format to facilitate data conversion.
- Mobile data collection sensors are more susceptible to damage or wear-and-tear than permanent data collection stations.

5. WEATHER INFORMATION SYSTEMS: STATE OF THE PRACTICE

Of the five focus areas, the need for high quality weather information was identified as a top priority for all of the districts. Although the elevations and types of weather problems encountered on rural roadways varied from district to district, adverse weather conditions were targeted as a concern for alerting motorists, deploying maintenance resources, and communicating with other agencies regarding road closures and establishing alternative routes.

The drastic changes in topography throughout Arizona present a challenge to all of the rural districts. The districts identified areas of concern for winter weather as typically those areas that are above an elevation of 3500 feet. Areas above that level experience severe weather conditions in the form of snow, ice and freezing rain. Lower areas experience dust storms and flooding. The varied weather, along with the unpredictable fire season each summer, constantly challenge each of the districts.

In the southern districts, dust storms and flooding are typical weather conditions that can cause critical impacts to freeway operations. The Safford, Tucson, and Yuma Districts all emphasized the need to alert motorists to low visibility conditions, and to advise them to seek alternative routes. In the northern districts, snow and ice removal were constant themes discussed during stakeholder interviews. The districts identified accurate weather forecasting as a primary concern for maintenance response, including snowplow dispatch, deicing chemical application, and freeway closures.

Snowplow operations were frequently mentioned as critical functions by the districts in the north. AVL-GPS technology is a tool to improve plowing efficiency. Chemical application monitors and weather sensors mounted on the vehicles were viewed as useful tools for managing anti-icing and deicing chemical application. There is significant interest in snowplow simulator training both within ADOT and at Coconino County. Each agency has a frequent need to hire new plow vehicle operators.

5.1 WEATHER INFORMATION SYSTEMS BUSINESS PLAN SURVEY

This section focuses on weather forecasting and integration of winter maintenance operations as well as flood detection business practices in Arizona.

5.1.1 Integrating Weather and Traffic Operations

The United States is in the midst of a culture change in surface transportation and weather operations.[10] Successful integration of these functional areas has the ability to provide significant benefits including:

- Improved Safety: Eliminating or reducing the severity of some of the 1.5 million weather-related crashes that take place each year and result in 7,400 fatalities and 690,000 injuries nationwide. Twenty-four percent of all crashes occurred on slick pavement or in adverse weather.

- Mobility Improvements: About 25 percent of non-recurrent delays on freeways are due to weather; system delay is 1 billion hours annually.
- Productivity Improvements for Motor Carriers: Weather-related delays add $3.4 billion to freight costs annually.
- Environmental Benefits: Carefully measured use of chemical anti-icing and deicing materials can minimize impacts on watersheds, air quality and infrastructure.

Two important areas in which technical advancements are being made are:

- Information Gathering: Examples include advancements in RWIS and low-cost weather stations, as well as in atmospheric science and modeling. These advancements now allow the National Weather Service (NWS) to provide forecasts down to a 5-mile grid.
- Information Sharing: The federal Clarus program and the Canadian Meteorological Mark-up Language (CMML) are both recent advancements in information sharing.

The Federal Highway Administration is investing in developing performance measures that can be used to evaluate and compare alternative road weather management strategies and the effectiveness of integrated weather and surface transportation operations. Initiatives underway include:

- Cooperative work with National Oceanic & Atmospheric Administration (NOAA) to identify performance measures for Road Weather Management.
- Development of winter maintenance performance standards (NCHRP 6-17).
- Improved benefit/cost analysis procedures for Road Weather Management tools.
- ITS deployment studies, including weather-responsive traffic management tools.

5.1.2 Weather Forecasting Services

A strong desire for high quality weather forecasts exists. This need can be met by various free and commercially available weather information services. Each service has advantages and limitations. Common trends in weather forecasting include:

- Tightening of the forecasting grid: better small-area "pinpoint" forecasts are becoming available through the application of more sophisticated computer-based forecasting models.
- Aggregation of weather data from multiple sources: the combining of sources increases the number of weather observations available both to the computerized models and the human user of the weather information. Both the US Clarus Initiative and the Canadian CMML initiative are examples of weather data aggregation programs.

Weather information sources for transportation operations can be categorized into four general classifications, and are discussed in the following sections:

- Official Weather Information Sources: The federally-funded weather information source in the United States is the National Weather Service.
- Free Weather Information Sources: This includes forecasting services provided by the news media in all formats. Unless rapport or a special relationship exists with the forecaster, no surface transportation-specific forecasts are provided.
- Professional Forecasting Services: These contract services provide site specific and surface transportation-focused weather forecasts; they may also be contracted by other industries to provide agricultural or recreational weather forecasting.
- In-house forecasting by DOTs: An emerging trend in the mountain states, led by UDOT. Dedicated year-round meteorologists and weather hazard (e.g. avalanche) mitigation specialists provide weather-related transportation safety services.

5.1.3 Official Weather Information Sources

The National Weather Service offers a variety of current weather condition forecasting and data products with focus on the aviation and maritime communities. As an element of the National Oceanic and Atmospheric Administration (NOAA), the NWS also issues a variety of weather related warnings and watches for hazardous conditions such as:

- Heavy Snow Warnings.
- Winter Storm Warnings.
- Storm Warnings.
- Snow Advisory.
- Flood Watch.
- Fire Weather Watch.
- High Wind Watch.

The I-40 corridor across Arizona is served by both the Las Vegas and Flagstaff offices of the National Weather Service. Forecasts and warnings may be accessed on the Internet at www.nws.noaa.gov**.** Similar information is available via VHF radio. There are fourteen one-hundred watt VHF weather information stations located throughout Arizona. The stations broadcast on the frequency of 162.4 or 162.55 MHz.

Some advantages and limitations of the NOAA forecasts are shown in Table 5 on p.58.

Table 5. Advantages and Limitations of NOAA Forecasts

ADVANTAGES	LIMITATIONS
• Local Forecast Offices • Watches and Warnings available for adverse weather • Local Expertise • Qualified Meteorologists • Up-to-Date Information • NOAA Radio • 24/7/365 Availability • Live Alerts • Good Internet Website • Radar • Satellite • Local Conditions • Climate • Forecasts • Historical Reports	• Consultation with multiple offices needed to get statewide information • Air transportation focus (rather than surface transportation focus) • General Forecasts • Forecasts for large areas • Limited Consultation Available • "Robot" Voice on NOAA Radio • Not Industry Specific (except for aviation)

5.1.4 Free Sources of Weather Forecasts

Some advantages and limitations of the free weather forecasts available from various media outlets are shown in Table 6.

Table 6. Advantages and Limitations of Free Weather Forecasts

ADVANTAGES	LIMITATIONS
Television	
• Local Expertise • Qualified Meteorologist • Storm Warning Notification • Radio (affiliate stations)	• Focus on Ratings Drives the Program • Content / Format / Time Limits • Focus on Urban Weather • No Accountability • Forecasts Available Only During News Hours • Consultation Unavailable
Radio	
• Typically Accessible • Storm Warning Notification • Frequent Weather Updates	• Urban Focus • Information Limited to Fit Station Format
Newspaper	
• Detailed Information • Prepared by Meteorologists	• Out-of-Date by Time of Delivery to Reader

ADVANTAGES	LIMITATIONS
Internet	
• Free • Easily Accessible • Lots of Info • Radar • Satellite • Maps • Conditions • Local Information (Zip code) • Conditions • Forecast • Radar • Warnings/Alerts • Lots of Sites	• Information may be Out-of-Date • Difficult to Assess Quality of Source • Updates Slow • May not be Locally Specific • Mix of Meteorologists / "web-designers" • Lots of Sites • Advertiser Driven

Examples of sites that provide weather information on the Internet include:

Web-based Weather Information	
www.intellicast.com	www.wunderground.com
www.weather.com	www.theweathernetwork.com
www.accuweather.com	

5.1.5 Commercial Forecasting Services

Commercial forecasting services are staffed by qualified consulting meteorologists with university degrees in meteorology or atmospheric science. The services provide forecasts customized for each of their customers and offer site specific forecasts and warnings. Consultation with meteorologists is an important part of the service. Transportation specific services that may be available include customized weather graphics, pavement specific temperature forecasts, and pavement treatment recommendations in accordance with the Maintenance Decision Support System (MDSS).[11] Services offered by professional forecasting services include:

- Consultation with Qualified Meteorologists.
- Site Specific Forecasts/Warnings.
- Forecasts customized for the customer.
- Industry Specific Forecasts.
- Customized Weather Graphics.
- Pavement-Specific Forecasts (from some, not all).
- MDSS (from some, not all).

Providers of customized forecasts include:

- DTN / Meteorlogix.
- Meridian Environmental Technology.
- Murray and Trettel, Inc. / Weather Command.
- Northwest Weather Net.
- The Weather Network.

Common questions that consulting meteorologists can answer include:

- Is the last forecast still accurate?
- What is your level of confidence in regard to this predicted event?
- If the forecast goes wrong, what other outcomes are possible?
- Why is it not precipitating here when the radar says it should?
- When will virga (light, wispy rain evaporating as it falls) reach the ground?
- Your forecast, and those of the TV, Radio and NWS, are all different. Why?

Reasons a DOT may wish to consider using a commercial forecasting service include:

- Freely available forecasts may not always be reliable.
- Freely available forecasts are not site-specific to rural roads and mountain passes.
- Freely available forecasts can not be customized.
- Freely available forecasts do not include meteorological consultation, 24/7.
- Private forecast services monitor forecast accuracy and work hard to keep accuracy levels high.
- Meteorologists can assist in interpreting radar data.
- The client can gain insight into the forecaster's level of confidence.

5.1.6 In-House Weather Forecasting by a DOT

Significant integration of weather and traffic operations at a TOC is relatively uncommon. Most centers respond to traffic, not weather. Weather information is limited to information from sources such as The Weather Channel and the DOT's environmental sensor stations. Weather information at most TOCs is used mainly for advisory purposes rather than developing treatment recommendations. The Utah DOT, however, has taken a more integrated and sophisticated approach.

UDOT developed an in-house weather forecasting program in 2002 for the Winter Olympics. The program includes a UDOT staff meteorologist supported by three contract meteorologists year-round, with a fourth meteorologist on staff during the winter months. Contract meteorologists are provided through Northwest Weathernet.

All of the meteorologists work on-site at UDOT's Salt Lake City TOC.[12] The UDOT weather forecasting program is intended to deliver pavement-specific forecasts for each of the department's 88 maintenance sheds. The target audience for the forecasts is:

- Winter Maintenance Personnel.
- Construction Crews.
- TOC Operations Managers.
- Senior Decision-makers.
- Law Enforcement Agencies.

Publicly-available weather forecasts do a good job predicting the amount of precipitation in the urban areas. The value added by the UDOT forecasting team is assessing how each storm will affect the roads in each maintenance area. Forecast quality is enhanced through thoughtful use of RWIS data and atmospheric science principles by a university-trained meteorologist.

The information is provided to UDOT employees with weather-related job functions such as maintenance and construction managers and snowplow operators. The UDOT weather team is available 24 hours a day, 365 days per year, to provide consultation with its internal customers. Each maintenance shed and law enforcement area will receive daily e-mail forecasts and consultation via an 800 number and the state radio system. Call volume averages 3,000 calls per year, with a single storm often sparking fifty or more calls. Maintenance staff may also access a web-based GIS map to obtain updated forecasts for each roadway segment.

Winter duties include pinpointing snowfall locations and making treatment recommendations. During the summer, weather forecasts are tailored to construction operations which must be performed within a specific temperature range, or during times when there is no anticipated precipitation. Examples of such construction operations include pavement and striping work. Forecasters also visit each roadway segment to learn the topography and fill gaps in the forecast data based on knowledge of the terrain

5.1.7 The *Clarus* Initiative

Clarus is a new program under development that will assimilate, quality check, and disseminate the nation's road weather observations.[13] The FHWA is investing in Clarus to demonstrate the system, and to establish partnerships to advance Clarus from a demonstration program to a full-scale deployment of a nationwide network.

Figure 7 depicts the integration of various weather data sources into the overall Clarus system. Data that may be included in the network are likely to include:

- RWIS or Environmental Sensing Station (ESS) data collected by state DOTs, including the ADOT data site network.
- Observations collected by NOAA and the National Weather Service.
- Data collected by the aviation industry, including Automated Weather Observing System (AWOS).
- Data collected by flood gauging stations and local/regional ALERT systems.

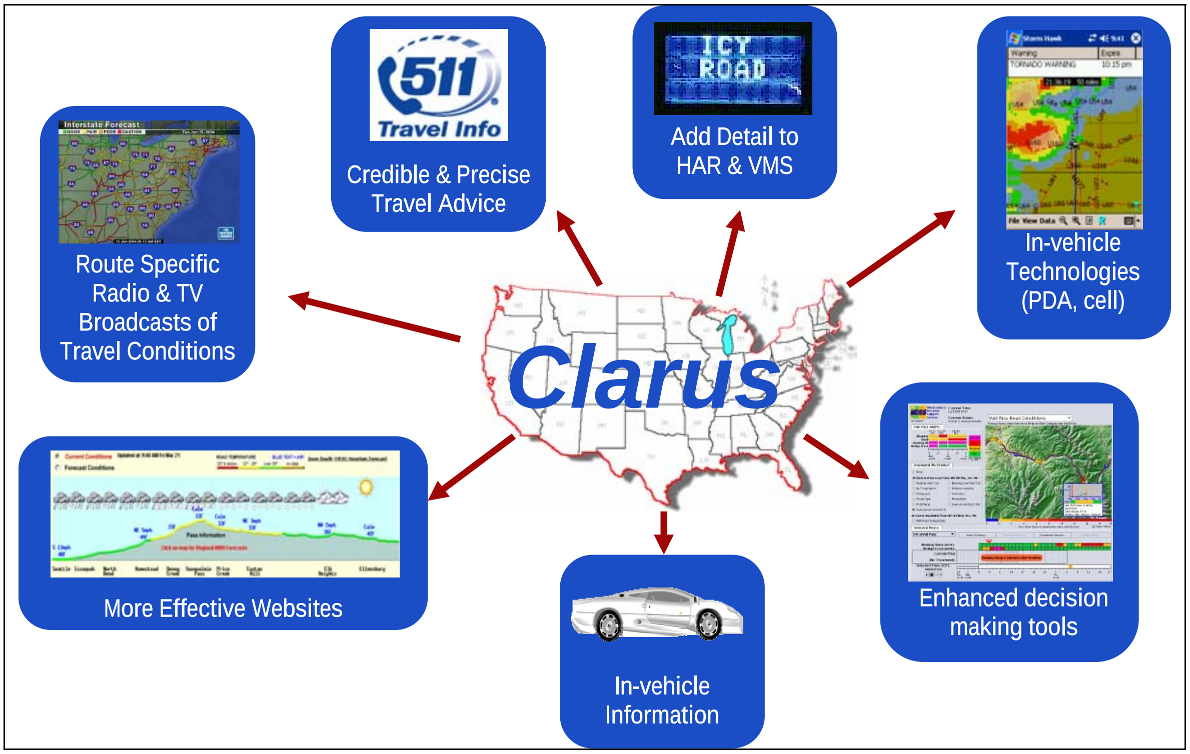


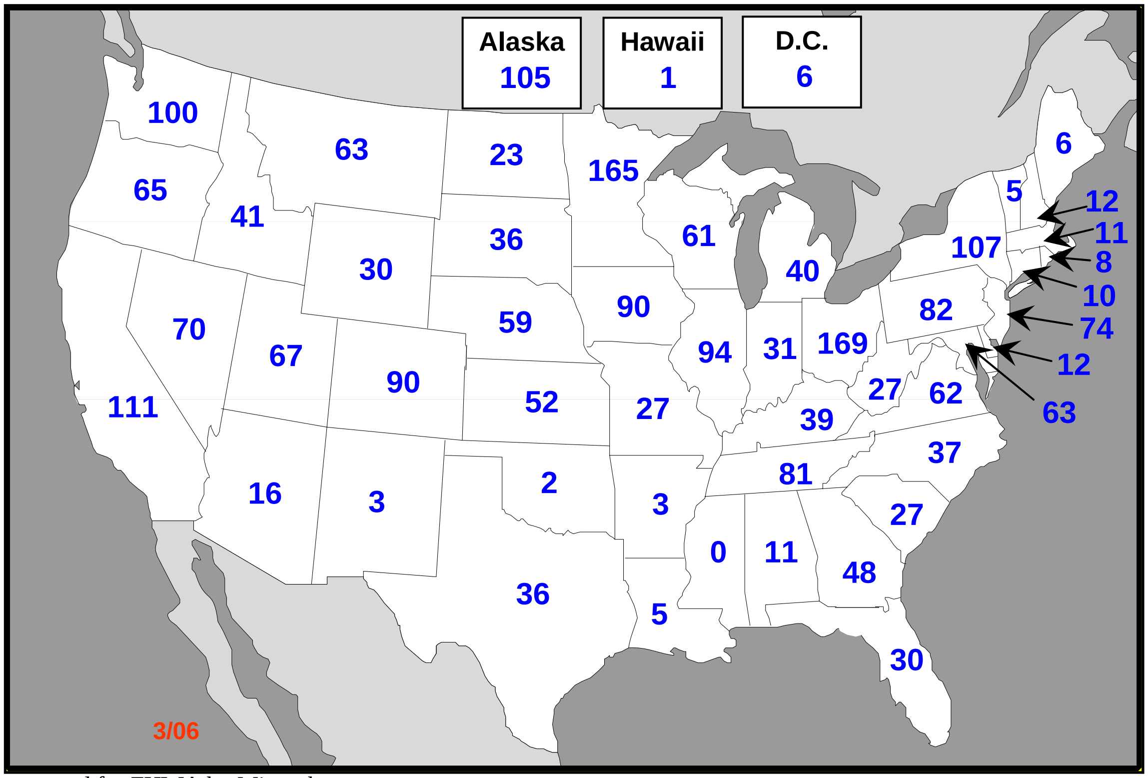
Figure 7. Clarus Network Vision

The specific benefit for Arizona of widespread regional deployment of Clarus would be the ability to take advantage of other states' ESS observations along the storm track. The opposite also is true, that observations from Arizona would assist adjacent states for weather predictions, supporting those other DOTs in a regional effort.

If winter storms approach Arizona from the northwest, some of the relevant out-of-state weather data sites may offer useful insights into regional storm patterns, as shown by Figure 8: there are 111 California ESS sites, 70 Nevada ESS sites, and 67 Utah ESS sites.

One of the limitations for storm predictions in Arizona is that New Mexico, and the northern states of Mexico, are likely to provide only very limited real-time ESS information on weather patterns. Many of Arizona's severe monsoon storms come from the east and south during the late-summer rainy season.

The Clarus program is expected to offer a significant opportunity to build an array of value-added services to disseminate high quality weather information to users. FHWA plans to conduct a multi-state demonstration of Clarus in 2007 and 2008, with nationwide deployment scheduled for 2009.



prepared for FHWA by Mitretek

Figure 8. ESS / RWIS Deployments by State as of 2006

The benefit to the Clarus user is the availability of a compilation of quality-checked local weather observations from multiple sources. In other words, a tighter grid of weather observations will be available through Clarus than through any of the individual systems.

As noted above, another broad regional benefit would be the availability of observations from nearby states and regions, as major storms approach, to help with predictions of storm severity and arrival time.

<u>5.1.8 Winter Maintenance Decision Support System</u>

The Maintenance Decision Support System (MDSS) is a nationwide winter maintenance resource. It combines advanced weather prediction, advanced road condition prediction, and rules of best practice for anti-icing and de-icing, to generate winter treatment recommendations on a route-by-route basis.

Figure 9 shows the user interface format, and the range of interpretive data provided. Other user interface screens plot parameters such as snow depth on the roadway, and provide specific treatment recommendations, including the chemical type and application rate in pounds per lane mile.

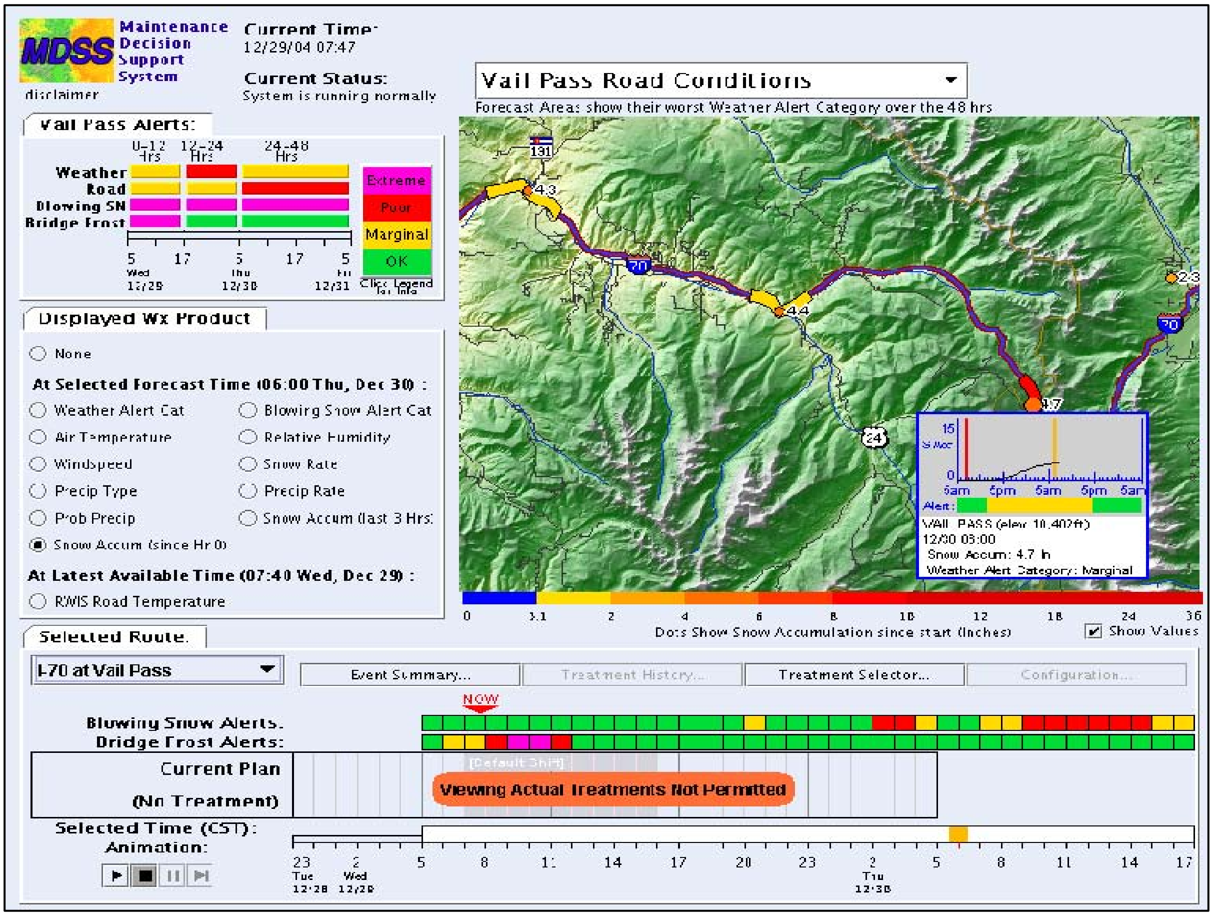


Figure 9. Maintenance Decision Support System User Interface

Advantages of MDSS include:

- Helps snowplow drivers have a better understanding of what should be done with respect to current conditions and forecasts.
- Reduces costs by aiding in proper chemical usage and application rates.
- Reduces the "Guesswork."

Currently there are two suppliers for MDSS. Meridian Environmental Technologies provides MDSS through a pooled fund program led by South Dakota. Participants in the pooled fund include South Dakota, North Dakota, Colorado, Wyoming, Iowa, Kansas, Minnesota, Indiana and New Hampshire. Additionally, Meteorlogix provides MDSS services to Idaho, Nevada, Nebraska, Missouri, Ohio New York and Maine.

5.1.9 Flood Detection Partnerships

Many County Flood Control Districts in Arizona have made significant investments in Automated Local Evaluation in Real Time (ALERT) systems to monitor the potential for flooding.[14] ALERT system stream gauging stations and sensors are typically interconnected to computers that have publicly available web-based interfaces to monitor the data. ALERT is a data reporting format that was developed by the National Weather Service for efficient collection of hydro-meteorological data in real-time.

The ALERT field hardware is housed in an aluminum standpipe. An enclosed tipping bucket rests atop the standpipe and measures precipitation by "tipping" back and forth with every increment of rainfall. Stream flow is measured by placing an instrument in the streambed, anchoring it with steel or PVC conduit, and running a cable into the standpipe. Power is provided to the transmitter from a 12-volt battery, which is recharged daily by a solar panel mounted to the top of the antenna mast on the standpipe.

The transmitter can be programmed to send data at regularly scheduled intervals, such as every 15 minutes, or at a specified incremental change. Sensors transmit data using VHF radio, via mountaintop repeaters. Most tipping buckets record every 0.04 inches (1 mm) of rainfall. Stream gauges are usually programmed to initiate a data transmission for every 0.6 inches (15.2 mm) of change in stream level, but can be programmed to transmit changes as small as 0.12 inches (3 mm).

Rainfall and stream flow are the two most common gauges used for flood warning, but some sites are equipped with additional sensors for measuring temperature, relative humidity, dew point, barometric pressure, wind speed and wind direction. Recently, sensors to indicate ice on roadways were installed in a few Arizona test locations.

Typical installations in Arizona use hardware manufactured by High Sierra Electronics. The estimated basic cost per station including installation is less than $10,000. Special sensors such as road surface condition, if required, may add to that figure.

These "weather stations" are scattered across the state and may provide, for example, useful data for predicting the onset of the monsoon season, or for indicating wind direction in the case of a wildfire.

ALERT data is collected through more than 500 of these weather data collection stations across the state, with sensor arrays ranging from precipitation measurement devices only, to full stations containing an assortment of measuring devices. Table 7 (p.66) shows the number of ALERT stations with weather data collection sensors for each county, as of July 2005.

Table 7. Breakdown of Weather Data Collection Stations by County in Arizona

COUNTY	NUMBER OF STATIONS
Cochise County	2
Coconino County	25
Gila County	12
Graham County	7
Greenlee County	8
La Paz County	5
Maricopa County	235
Mohave County	58
Navajo County	31
Pima County	84
Pinal County	28
Yavapi County	63
TOTAL	551

5.1.9.1 - Representative County ALERT Programs

The following subsections provide brief summaries and maps to illustrate some of the key deployment programs by individual county flood control districts in Arizona.

Mohave County: Mohave County has the most mature and sophisticated ALERT system in Arizona. The program began in December 2001, when the Arizona Department of Water Resources (ADWR) installed 17 monitoring sites throughout the County.

Between 2002 and 2006, Mohave County drastically accelerated the deployment program, bringing the County total to 58 individual sites that collect data through various sensors, as shown in Figure 10. These stations will provide real-time regional data monitoring in the event of weather-related emergencies.

ADOT's Kingman District has entered into an interagency agreement with Mohave County to access the system database and to jointly deploy additional ALERT stations and sensor types. Mohave County shares its ALERT data with Nevada and Utah, but does not currently receive data from either of those states.

The County's cooperative agreement with ADOT offers a model for other districts across the state to obtain real-time weather data from their regional partners at a relatively low cost. While not as varied or detailed as ADOT's RWIS data resources, the many sites available offer many more points of weather data than are currently available for planning and response.

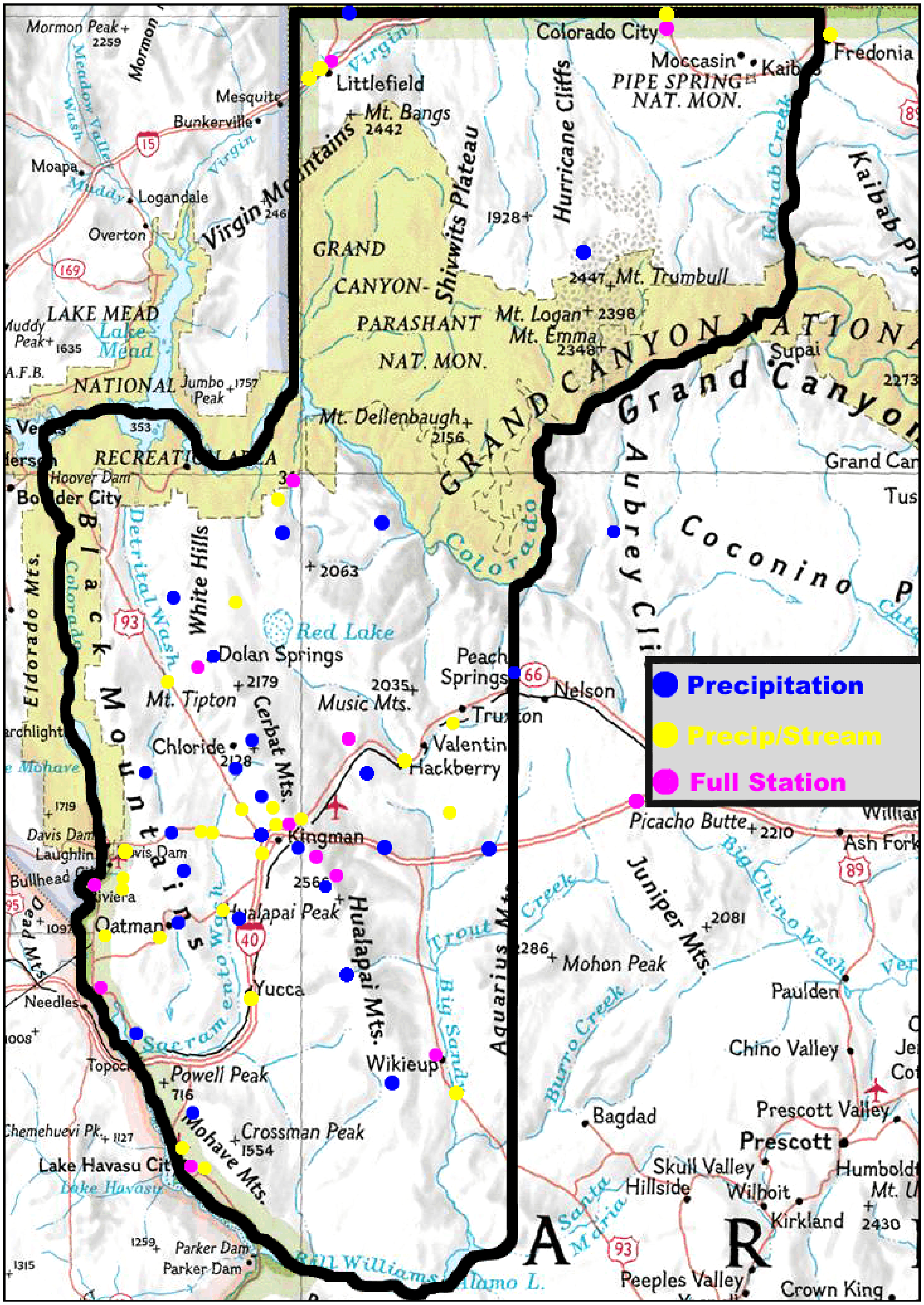


Figure 10. Mohave County ALERT Station Sites

Pima County: The Pima County Regional Flood Control District operates and maintains a network of real-time sensors used to collect hydro-meteorological data. This network provides information to the District and other agencies about precipitation, storm-water runoff, and weather conditions affecting watersheds within Pima County.

The Pima County ALERT system consists of a fully automated regional network that includes 84 precipitation sensors, 30 stream stage sensors, and four weather stations operating in eastern Pima County and adjoining counties, as shown in Figure 11.

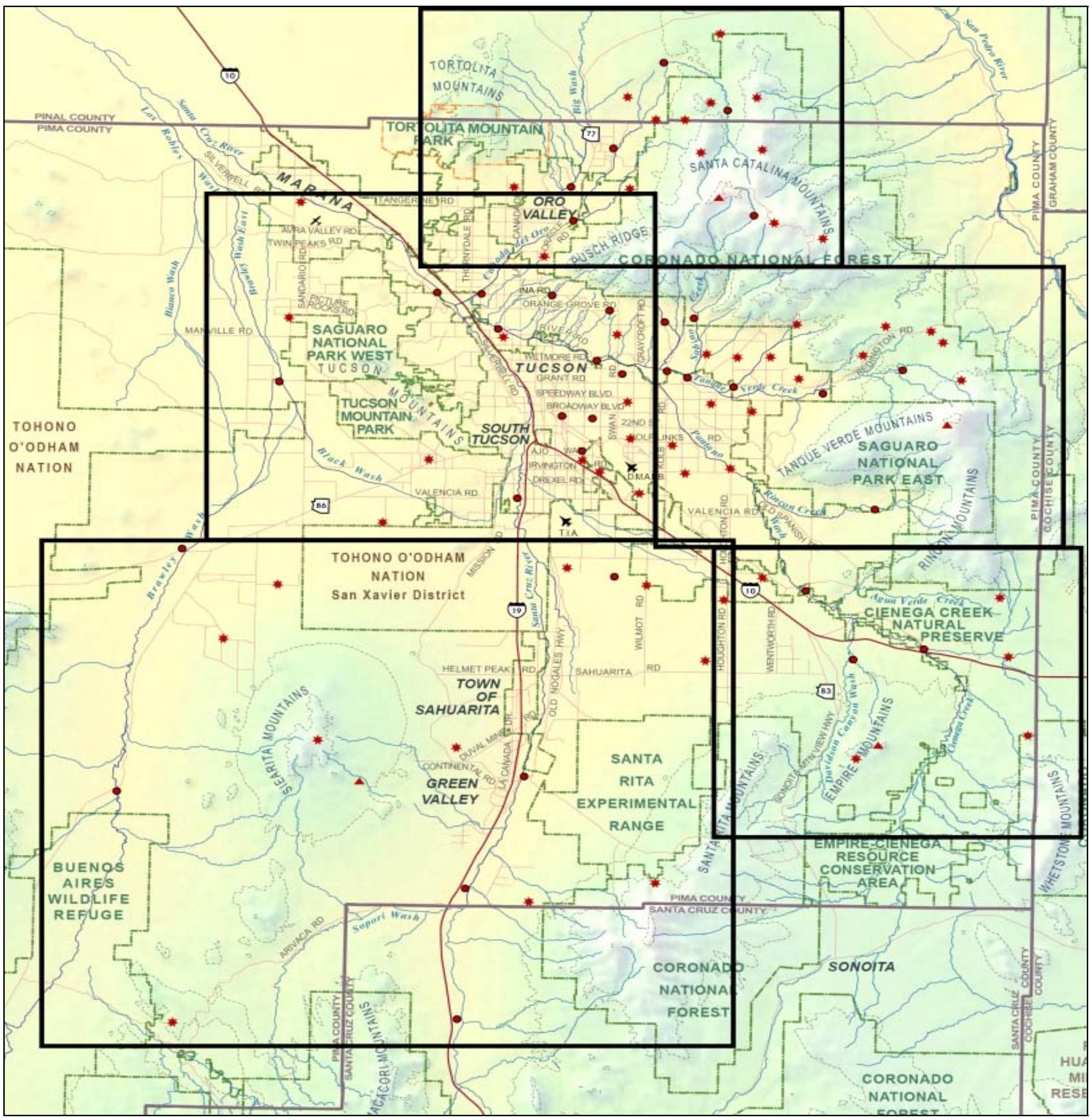


Figure 11. Pima County ALERT Station Locations

Maricopa County: The Flood Control District of Maricopa County operates a 24-hour rain, stream, and weather gauge network, which provides "real time" information to the County and many other agencies about rainfall, stormwater runoff, and weather conditions across the region of influence.

This network operates in the National Weather Service ALERT format. In addition to rainfall and stream flow, the gauges measure temperature, humidity, wind speed, barometric pressure, wind direction and solar radiation. The ALERT system uses "automatic" telemetry gauges linked through VHF radios. The locations of the Maricopa County site network are shown in Figure 12.

This basic weather data can be viewed at http://156.42.96.39/alert/Wx/wcurrent.txt, along with relevant upper-watershed data from several of the adjacent Yavapai County sensor stations as well.

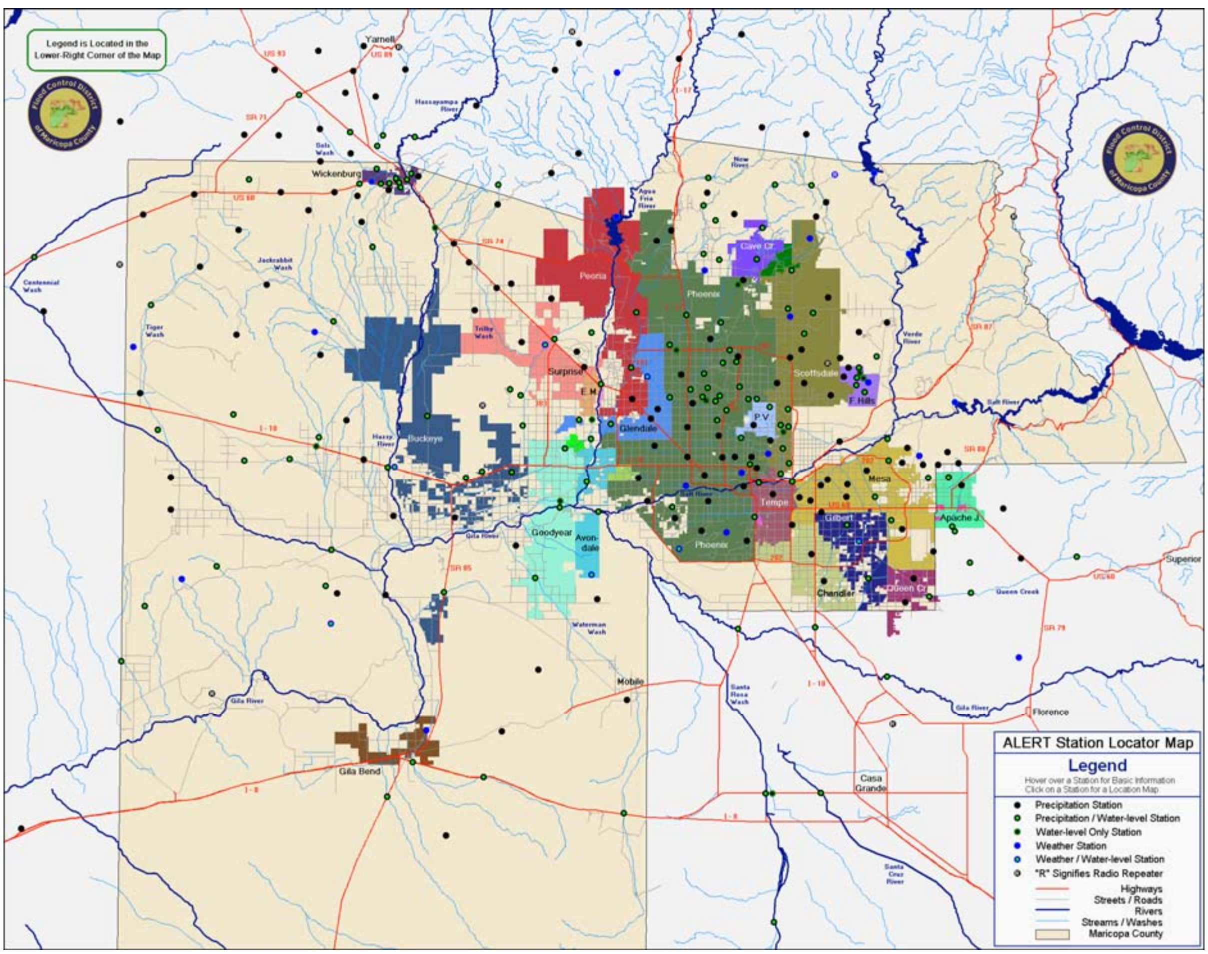


Figure 12. Maricopa County ALERT Station Locations

Yavapai County: This regional ALERT system is comprised of 63 sensing stations that primarily cover the Sedona / Oak Creek watershed, and the mountainous regions south and west of Prescott, as illustrated in Figure 13.

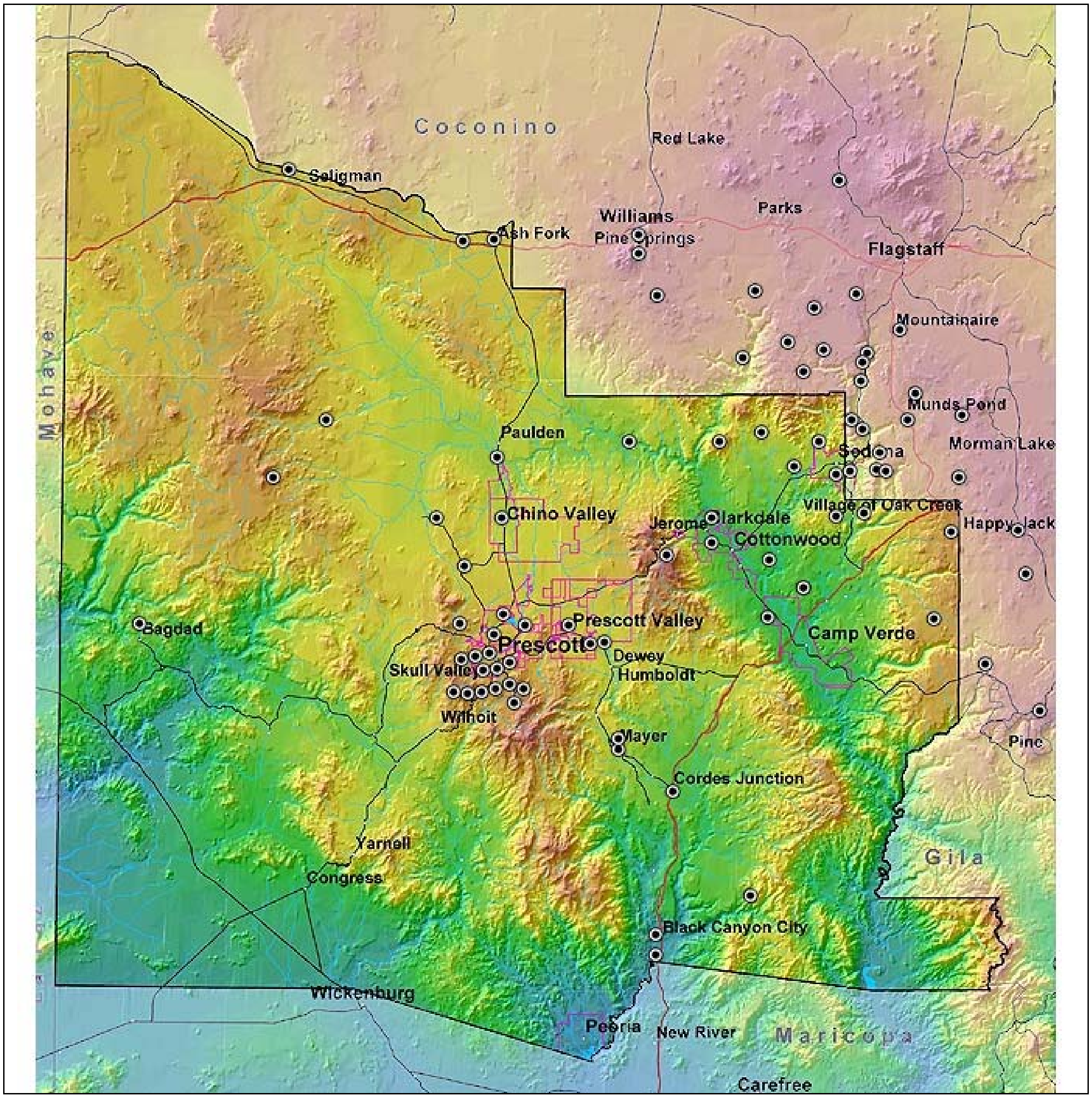


Figure 13. Yavapai County ALERT Station Sites

<u>5.1.9.2 - Intergovernmental Relationships</u>

Other ADOT districts may wish to follow the model of the Kingman District to share resources with their county flood control districts to better assess the potential for flooding on roadways. The Kingman District's Mohave County intergovernmental agreement enabled the joint use of the ALERT system networks that have been deployed across many Arizona counties. Some coordination with the Arizona Department of Water Resources may also be appropriate, as that agency has a statutory duty to coordinate with the federal government, state agencies, and local entities such as county flood control districts to establish a statewide Flood Warning System.

The Arizona Department of Water Resources Flood Warning Unit actively coordinates the combined efforts of multiple entities to warn the public of potential floods. These include such federal agencies as the National Weather Service (NWS), the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), the Natural Resources Conservation Service (NRCS), and the Bureau of Reclamation (BOR).

At the state level, there is an open line of communication with the Arizona Division of Emergency Management during times of flood potential. At the local level, the Flood Warning Unit works with county flood control districts and the Salt River Project to facilitate the sharing of data critical to evaluating potential threats from flooding.

5.1.10 National Initiatives

Nationwide agency coordination has further improved the level of cooperation for relating experiences with weather information systems and related agency resources. These national-level programs include:

- Aurora Pooled Fund Program - This program unites 16 state and regional transportation departments with an interest in RWIS into a cooperative effort for common research goals.
- Clear Roads Pooled Fund Program - This is a state pooled fund research program for rigorous testing of winter maintenance materials, equipment, and methods for use by highway maintenance crews.
- Clarus Initiative – This program is a nationwide effort to network state resources at a federal level. State RWIS data will be standardized and made available at a single-point source. Clarus is developing an integrated nationwide surface weather observing, forecasting, and data management system to alleviate the effects of adverse weather on surface transportation (see also Section 5.1.7).
- Maintenance Decision Support System (MDSS) Program – Road maintenance agencies for every level of government will coordinate experiences with new technologies to optimize anti-icing and snow and ice control expenditures via enhanced decision making (see also Section 5.1.8).
- ENTERPRISE Pooled Fund Program – This program is a pooled fund study with 13 member agencies from North America and Europe. Its main purpose is to use the pooled resources of its members, private sector partners and the United States federal government to develop, evaluate and deploy ITS elements. ENTERPRISE facilitates sharing of technological and institutional experiences gained from joint ITS projects, and from the projects of its individual members, including ADOT.

5.2 WEATHER INFORMATION SYSTEMS TECHNOLOGY SURVEY

Specific regional needs were identified throughout the interview process with the individual districts. Specific challenges vary based on typical elevations, ranging from dust storms and flooding in the southern districts to snow storms in the northern districts. With Arizona's drastically diverse terrain and weather challenges, a wide scope is necessary to review the range of current technologies available.

Road Weather Information Systems consist of three major components. Environment sensors detect and collect a multitude of weather information including air temperature, dew point, relative humidity, barometric pressure, precipitation type, precipitation rate, wind speeds, wind direction, visibility distance, pavement surface temperature, pavement freezing point, pavement surface condition, pavement chemical composition, and subsurface conditions. These RWIS sensors are typically deployed as one unit, an Environmental Sensing Station (ESS).

The second key component of RWIS is software that uses algorithms to process data and develop weather forecasts. These algorithms incorporate both real-time data received from deployed ESS and historical data to help predict weather conditions and instigate warning systems.

A third RWIS component is the information dissemination tools to deliver pertinent information to those that can benefit most from advanced warnings of roadway conditions. By presenting the data in a user-friendly format, the system operators can better apply their time to tasks at hand, and to delivering information to motorists in a timely fashion. These weather information delivery tools include variable message signs, highway advisory radio, and any other information delivery tool available to the agency.

This survey includes any technology that may meet the needs based on weather-specific challenges for the entire state. These technologies were identified via the district staff interview process, brainstormed in the initial project conception, or discovered through independent research. The concepts reviewed include Flood Detection, Weather Forecasting, Weather Sensors, Bridge Deck Monitoring, Black Ice Monitoring, Dust Storm Monitoring, and Portable RWIS.

The diverse topography of Arizona results in varied needs from district to district. Specific weather events may include precipitation, low visibility conditions, high winds, sleet, snow or ice storms, dust storms, rain storms and flooding, and resulting rock slides.

ADOT uses several key indicators to make operational decisions, including atmospheric data and pavement condition data. Atmospheric data includes precipitation, air temperature, dew point and relative humidity, and visibility distance. Pavement condition data includes wetness, freeze point temperature, and chemical concentration.

5.2.1 Roadway Icing Monitors

Roadway Icing Monitor systems address a number of safety issues and provide solutions for improving road conditions by preventing the formation of ice in spot locations. Fixed anti-icing/deicing systems detect ice in likely locations, such as bridge decks or shady areas, and can treat the roadway before it becomes hazardous to drivers. These systems require environmental or in-road sensors, a processor to determine when conditions require de-icing, and a device for removing ice.

Highway anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. It provides a maintenance manager with two major advantages: the capability to maintain roads in the best conditions possible during a winter storm, and, the ability to do so in the most efficient manner. As a consequence, ITS anti-icing tools have the potential to provide the benefit of increased traffic safety at the lowest cost.

The Federal Highway Administration sponsored a project to develop clear guidelines for standardizing roadway anti-icing programs. Report No. FHWA-RD-95-202 (June 1996) is titled *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel.*[15]

One of the primary anti-icing measures identified in the report is the application of liquid chemical. An even distribution of the chemical is dispersed prior to snow accumulation. The chemical spray releases the anti-icing agent uniformly over a predetermined area of roadway where ice is expected to form. The two types of liquid application equipment are spinners with rotating disks, and spray nozzles mounted to a distributor bar.

Challenges exist for both types of liquid chemical dispensers. The nozzle type can have problems with nozzles plugging, or can dispense such a fine mist that it disperses before hitting the pavement surface. Spinner disks can dispense liquid droplets that are too large for uniform coating of the pavement surface.

5.2.2 Automated Anti-Icing

At identified locations susceptible to the formation of black ice, a proactive monitor can determine when to dispense automated anti-icing sprays. This automated anti-icing and deicing system uses accepted liquid freezing point depressants and traditional spray application techniques, with RWIS data communication and process controls to initiate and perform the task.

Automated anti-icing systems can be deployed at any fixed location to provide anti-icing treatment of a bridge, ramp, or other targeted area of roadway.[16] The system dispenses de-icing agent by pumping the chemical through a sequence of high-pressure spray nozzles. Upon activation, the system activates the pump and automatically sequences the nozzles to spray the de-icing liquid over the targeted area. Special diagnostic tools allow the flow and pressure sensors to be monitored for maintenance.

Automatic activation of anti-icing systems is enabled with an ice prediction system that accurately measures pavement surface conditions. This system utilizes a pavement sensor that uses specific measurements to determine the state of the pavement surface. Specific data is collected, including water-layer thickness, depression of freezing point, and chemical concentration, to provide ice and frost warning conditions. A computer algorithm uses the measurements and collected data to automatically activate the anti-icing system when icing conditions are predicted.

A prototype system was installed on an I-215 overpass/interchange in metropolitan Salt Lake City and analyzed for the 1997-98 winter season.[17] This curved bridge deck has six lanes and is over 400 ft in length. Comparing the collected data with records from the previous five winter seasons, a 64% reduction in snow and ice-related accidents was reported on the northbound lanes. The project verified that fixed bridge deck snow and ice control material broadcast systems can significantly and cost-effectively enhance motorist safety during icing conditions, relative to the present over-the-road methods of operation. The total cost for this installation was $250,000.

The University of Kentucky has also performed an evaluation of an automated anti-icing system.[18] A bridge deck anti-icing system was installed on a bridge on I-75 in Corbin, Kentucky, in late 1997. The system had 11 parapet-mounted/bridge rail-mounted spray nozzles per side to treat the two travel lanes with the anti-icing agent. The system dispenses 8 gallons of anti-icing agent per application to cover the entire bridge. After four winter seasons, only minimal issues were experienced with the system. It was recommended that the system be used in crash-prone areas, remote locations where bad weather can affect operator safety, rural locations not cost efficient for truck deployment, and all bridges with significant moisture content.

5.2.3 Integrated Weather Information Systems and Traveler Information Systems

Freeway management can be enhanced with the integration of Road Weather Information Systems and Traveler Information Systems. Real-time surface conditions can be detected through RWIS and can alert freeway management operators to changes in roadway conditions so that they can update the ITS information resources. This real-time traveler information can be provided to motorists as may be indicated by the weather conditions using dynamic message signs, variable speed limit signs, highway advisory radio, and weather advisory systems. Other benefits include accelerated incident response, improved roadway safety, and an ability to advise motorists about alternative routes.

A recent project in San Joaquin County, California involved 36 vehicle detection sites and nine ESS's deployed along the freeways in an effort to combat low visibility conditions.[19] During the winter, localized fog can be severe, while in the summer, wind-blown dust often restricts visibility. Numerous chain-reaction collisions have been attributed to the resultant poor visibility in the Stockton-Manteca area.

The sites for this project collect traffic and weather data. The vehicle detection sites consist of paired inductive loop detectors and controllers. These controllers run software with speed measurement algorithms. Each ESS includes:

- A rain gauge.
- A forward-scatter visibility sensor.
- Wind speed and direction sensors.
- Relative humidity sensors.
- A thermometer.
- A barometer.
- A remote processing unit.

The traffic and environmental data are transmitted from these stations to the Stockton Traffic Management Center's (TMC) networked computer system through dedicated, leased telephone lines. The central computer system automatically displays advisories on nine DMS on the two roads, designed specifically for readability in adverse weather. TMC operators can forward the warnings to other service providers including the media, Caltrans short-range radio stations, and a traffic congestion hotline.

Caltrans is considering expanding the system by making the following improvements:

- Integrating the monitoring and control computers into a single workstation.
- Adding a closed circuit television (CCTV) surveillance system to visually verify roadway conditions.
- Adding an HAR system to supplement the visual warning messages being displayed on the DMS.
- Testing variable speed limit technology and pavement lights.
- Interfacing the system with the CHP information system.

5.2.4 Low Visibility Detection and Warning Systems

Another component of RWIS is low visibility detection. Integrated with a warning system, this system can alert freeway operators to adverse driving conditions.

Deployment of fog detection and warning systems in Tennessee reduced the number of fog-related crashes from more than 200 incidents between the years 1973 and 1993 to a single incident between 1994 and 2002.[20] The system deployed by Tennessee DOT uses data received from two environmental sensor stations, eight forward-scatter visibility sensors, and 44 vehicle detectors. Sensor data communicates via fiber optic with an on-site computer for processing, which is then transmitted to a central computer by a microwave communication system. When the data indicates low visibility conditions, system managers can activate six static signs with flashing beacons, two HAR transmitters, and ten DMS to notify motorists.

The Tennessee system also uses a variable speed limit sign that indicates a fog warning and an associated speed limit reduction. Specific challenges to deployment included hardware failures due to harsh weather conditions, lightning protection systems installation, communication disruptions due to misaligned antennas, and regional communications issues with data transmission.

Caltrans also has initiated a program called "Operation Fog" in an effort to alert motorists to potentially harmful situations involving natural, weather-based hazards.[21] Along with motorist education, the key ITS component of the program is the Caltrans Advanced Warning System (CAWS), consisting of 9 DMS, 9 weather stations, and 36 speed monitor locations along southbound I-5 and westbound Highway 120 near Stockton. In service since 1996, CAWS covers 15 miles in an area known for dense recurrent fog, particularly at peak commute hours.

The CAWS system is fully automated, with temperature probes providing accurate temperature and relative humidity measurements and speed monitors that detect slow and stopped traffic. As the data is gathered and calculated, DMS display warnings such as "Foggy Conditions Ahead," "Dense Fog Ahead," or "Caution Slow Traffic Ahead."

Challenges to the system include a delayed response time between the triggering event and message relay to the DMS. This delay averaged over 7 minutes for fog messages and between 3 and 6 minutes for traffic warning messages.[22] Maintenance was also a challenge, where the system was vulnerable to single points of failure. The system also includes 210 inductive loops, and 72 precision weather instruments, communicating over 45 individual telecom circuits. This system was identified as needing improvement.

5.2.5 License Plate Recognition (LPR)

This technology captures license plate images and, using optical character recognition software, interprets the images into text and stores the data into a database. The data is date- and time-stamped, allowing for a comparison between two separate license plate readers placed at a known distance apart from each other.

Once the two separate databases are cross-referenced to each other, individual vehicle speeds can be computed. A series of speed calculations can provide the average speed over a designated stretch of roadway to compute the expected travel time, in order to post public advisory notices.

While most of the applications for LPR technology deal with parking facilities, numerous products provide information relevant to ITS goals and applications. Each vendor uses the same techniques to capture license plates, and provides the same information.

Arizona initiated a new program in mid-2006 using LPR technology to assist in stolen vehicle detection.[23] The LPR cameras are mounted to the front bumpers of DPS highway patrol cars, with a keyboard and monitor system installed in the front seat of the car, as is shown in Figure 14.

Scanning any passing vehicle's license plate, the system is capable of instantly reading and processing the plate and running it through a database, alerting the patrol officer if it is stolen or otherwise 'wanted.'

The LPR system, as utilized by Arizona DPS, can also actively scan for specific license plates under the AMBER Alert system, if the officer manually enters the suspected license plate number for scanning.

Figure 14. LPR Technology Installation for DPS Vehicles

Five DPS patrol vehicles were initially outfitted with an LPR system, with additional installations planned. Able to process nearly 1,500 license plates in an 8-hour shift, the system is anticipated to reduce Arizona’s stolen vehicle rate, one of the highest in the nation. Each device costs approximately $38,000 to purchase and install.

6. HIGHWAY ADVISORY RADIO: STATE OF THE PRACTICE

This chapter discusses strategies for Highway Advisory Radio (HAR) systems for rural Arizona. Due to the emerging trends in radio broadcasting, the research approach takes a broader view of the subject, also examining a variety of trends and business practices for the dissemination of traveler information via radio.

HAR was identified in interviews as a tool used to alert motorists of changing roadway conditions. ADOT field staff reported excellent success with the use of one particular vendor's traveler information station service. The typical deployment of HAR by ADOT has been in conjunction with construction projects. Motorists entering work zones were instructed to tune their radios to a specified station to receive updates on the construction. This is a powerful method to deliver information to travelers, as explored in this section.

Some of the needs related to HAR as discussed in the stakeholder interviews indicate other situations in which ADOT would like to deploy HAR. These include work zones, ports of entry, rest areas, traveler information (corridor-wide), and potential road hazards.

Along with variable message signs and commercial radio traffic reporting, HAR is one of the oldest traveler information technologies. A typical Highway Advisory Radio system transfers information from a central point into the field, delivering information to either permanent or portable HAR units.[24] This communication can be done by any typical communication method including dial-up, fiber optic, cellular, or satellite. Ideally, as conditions change, information broadcasted from the HAR would remain relevant to motorists by being updated to reflect the latest roadway conditions.

The broadcast range may vary from one to six miles, depending on the power of the transmitter, and the surrounding terrain. Nearly all HAR systems use the AM band. According to federal regulations, HAR broadcasts may not contain entertainment or commercial messages. They are often used in conjunction with variable message signs, which will tell drivers where or when to tune to HAR. A HAR broadcast can include more specific information than a commercial traffic report or a variable message sign, as there are no commercial constraints and motorists can be exposed to a message for longer periods of time. Another advantage over commercial broadcasts is that it can be available 24 hours a day. No additional equipment is needed to receive highway advisory radio broadcasts since most vehicles and trucks have AM radios.

Information relayed to motorists through the use of HAR includes:

- Construction project information on work zone restrictions and closure durations.
- Hazardous roadway conditions caused by inclement weather.
- Operating restrictions such as requirements to put on snow tires or chains.
- Warnings of hazards such as forest fires, floods, mudslides or highway closures.

- Traffic conditions along short segments of specific routes, especially work zones.
- Alternative recommended detour routes.
- Directions and information for tourist attractions.
- Parking availability.
- Public transit alternatives.
- Notices of events.

HAR is typically deployed as “active systems” for major construction projects with changing conditions and typically congested segments of the roadway, and in “closed systems” such as national parks and airports. A variation of HAR deployed in Europe is used to broadcast to on-board receivers, where messages are customized according to the vehicle's location. As Internet-ready digital cellular transceivers become standard options in new vehicles in the U.S., they may also be linked with Web-based radio systems.

Some of the challenges of implementing HAR include:

- Maintaining accurate, up-to-date messages to be relayed to motorists.
- Designing messages so that they are comprehensive yet succinct.
- Maintaining AM signals at a quality that is clear and enjoyable to listen to.
- Providing reliable power for 24-hour operation.
- Providing adequate coverage across a limited area.

One of the chief components of cost for HAR is the key task of keeping the information current. This task is labor-intensive. Under some conditions, placing, installing and maintaining antennas can be costly, as well as the staffing and equipping of a central control facility to coordinate information from multiple agencies.

6.1 RADIO AS A TRAVELER INFORMATION DELIVERY TOOL

The radio is an excellent tool for delivering traveler information. There are over 200 million registered vehicles in the United States with 75% of the population aged 12 or over listening to radio on a daily basis. Currently 80% of all radio listening takes place in a vehicle.[25] 93% of the US population listens to AM/FM radio at least once per week.

Cell phones are the only other audio device approaching the market penetration of terrestrial radio with 76% of the entire US population owning cell phones in 2006, and 233 million subscribers.[26]

There are several potential technologies for delivering roadway and traveler information via radio or wireless methods. The methods are summarized in Table 8.

Table 8. Technologies to Deliver Traveler Information via Wireless Communications

Description	Operated by	Range	Content	Notes
Low Power AM	Anyone	200 Feet 100 milliwatt Power Limitation	Most Anything (e.g. Talking Houses)	
AM TIS/HAR Stations	Government Agencies	5 to 10 miles 10 Watt Power Limitation	Traveler Information Only	
Low Power FM Stations	Churches	3 to 6 miles	Specialty and community programming	1,124 FM radio license records exist in the FCC database for Arizona
AM Broadcast Stations	Licensed Commercial Broadcasters	100 to 1000 miles 50,000 Watt Power Limitation	News, Talk, Sports, Etc.	93% of the population listens to AM/FM radio weekly
FM Broadcast Stations	Licensed Commercial Broadcasters	Up to 100,000 Watts 50 to 100 miles	Music, sports, talk, etc.	93% of the population listens to AM/FM radio weekly
Satellite Radio	XM Sirius	Continental US	Music, news, sports, traffic, weatherlink service. Controversial programming – No FCC censorship.	7 million subscribers, 20 million subscribers by 2010
HD Radio	Commercial Broadcasters	Similar to AM & FM Radio	Music, sports, talk, etc.	17 stations are now on the air in Arizona
Cellular Telephones	Internet Radio Programming may become available on cellphones in the near future as a subscription service offered by cellular carriers	Within 3 miles of a cellular tower	Cell phones are emerging as a multi-purpose communications and entertainment device	70.3% market penetration for cell phones
Podcasting	Anyone	Anywhere with internet access	Anything	A podcast is a digital recording of a radio broadcast or audio program, made available on the Internet for downloading to a personal audio player.

6.1.1 Low Power AM Stations

This service operates in the AM broadcast band and transmits just several hundred feet. This equipment is regulated to limit transmitter power to 100 milliwatts, under Part 15 of the FCC rules. This type of service is sometimes used for "talking house" applications, but could be suitable for select transportation applications, such as rest area information. Key characteristics of low power AM stations are:

- Can be operated by anyone.
- Any content that does not interfere with other users is permitted.
- Only ~200 foot range.
- Very few listeners.
- Mature technology.
- May be useful for rest areas and special applications.
- Low cost.

6.1.2 AM TIS/HAR Stations

This is the most common type of traveler information station operated by a DOT. Under the FCC rules, traveler information stations (TIS) typically operated by city or county authorities to provide tourist information, and Highway Advisory Radio stations operated by DOTs, are both authorized.[27] Per the FCC rules,[28] Traveler Information Stations operate in the AM Broadcast Band (530 kHz - 1700 kHz) and are limited to a 10 watt transmitter output power. Antenna height may not exceed 15 meters (49.2 feet). These stations may not transmit commercial information. This service is not available to individuals or groups, but only to governmental entities and park districts. Users report a coverage radius between 5 and 10 miles.

Key characteristics of AM TIS/HAR stations are:

- Operated exclusively by government agencies.
- Content restricted to non-commercial highway or traveler information.
- Range of 5 to 10 miles with an ability to create broad coverage areas using multiple synchronized transmitters.
- Limited number of listeners.
- Mature technology.
- Widely used for special event traffic management, work zone information, and tourist information at parks.
- Moderate cost: Department-owned equipment can be purchased for less than $10,000 for hardware. Services for turnkey set-up and operation of these stations may cost from $900 to $1,800 per month from local vendors.

6.1.3 Synchronized HAR AM Broadcasting

This technology addresses the problem of broadcasting interference when multiple HAR signals overlap. When a HAR station is relatively close to another station, broadcasting on the same frequency can cause interference resulting in an incomprehensible message that can confuse a listening motorist. Being able to synchronize the broadcasts can minimize interference and allow for continuous broadcasting on a single message over a broader range. Synchronized HAR broadcasting has the same key characteristics as regular HAR stations. In addition, HAR systems using GPS acquire a signal from three or more satellites; this provides a highly accurate time source, which is used as a reference point. Using the GPS signal allows the frequencies from multiple transmitters to be synchronized, and stay phase-locked indefinitely.

By using the GPS synchronization, there is no signal interference or cross-over messages in zones that overlap. The broadcast coverage is clear throughout the broadcast area, with the listeners perceiving one, unified broadcast. The audio is then synchronized using the same GPS signal, allowing all the radio stations in the array to launch their messages within 1 millisecond of each other. There is no limit to the number of transmitters that could be used in this system. By having a decentralized system such as this, communications costs are minimal. Using a GPS synchronized array of HARs to cover a large area seamlessly also provides for scalability. As demand for coverage increases, additional transmitters can be added to the array to increase coverage.

The City of Miramar, Florida implemented an AM GPS Synchronized System after determining that an ideal system would be able to broadcast messages throughout the entire city, not just in a localized area such as a park or only one section of the city.[29] The agency is using an AM transmitter with advanced GPS technology to communicate messages to its residents. The broadcast range for the system typically covers a four to six mile radius, and is often used for safety information, local points of interest, public events, construction zones or frequently congested traffic areas.

The City uses the system to inform residents about upcoming events, parks and recreation activities, announcements about traffic, and general safety messages; they also used it for warnings of Hurricane Katrina when it passed over Florida. The city changes the messages as regular events come and go, and has a library of safety messages, rotating them as well. The City plans to expand use of the product by working with the fire department to broadcast messages about fire prevention, and has even considered using the frequency for elected officials to communicate city-related messages.

6.1.4 Low Power FM Stations

In 2000, the Federal Communications Commission (FCC) authorized new, non-commercial Low Power FM (LPFM) broadcast stations throughout the FM band at powers of up to 100 watts with antennas up to 100 feet tall. This approach could allow high quality coverage for an area that is three to six miles in diameter at a cost of approximately $12,000 per site. The Iowa DOT and the ENTERPRISE Pooled Fund Study Group[30] see the new FCC rules[31] as providing a unique opportunity to get rural roadway, weather and tourism information into every car and truck at a reasonable cost, as FM offers higher quality reception and other benefits over traditional AM Highway Advisory Radio. Currently there are no known low power FM stations in use by a transportation agency. Through concerted lobbying efforts and the actions of trade groups, the radio broadcast industry has effectively prevented the commissioning of any known LPFM station for TIS or HAR application.

Key characteristics of low power FM stations are:

- They may be operated by FCC licensed non-commercial entities such as churches, community groups, schools, etc.
- They offer niche programming that is of interest to the sponsoring group's members or target audience.
- The range for a low power FM station can be up to 6 miles.
- There are relatively few listeners in the small area.
- It is a mature equipment technology, but impractical for HAR/TIS. The regulatory climate for this FM radio application is relatively new and in a state of flux. The National Association of Broadcasters (NAB) is actively lobbying against HAR and TIS use under the new low power FM rules.

6.1.5 Satellite Radio

Satellite radio technology uses a digital receiver for signals broadcast by communications satellite, which covers a much wider geographical range than terrestrial radio signals. Satellite radio functions anywhere there is clear line-of-sight between the antenna and the satellite, given there are no major obstructions such as tunnels or buildings. Audiences can follow a single channel while traveling, basically regardless of their location.

This technology requires access to a commercial satellite for signal transmission. The satellite radio services are commercial entities which offer a package of channels as part of their service, for a user subscription fee. These and other services have news, weather, sports, and numerous music channels. All current services are proprietary and deliver non-compatible signals, requiring proprietary hardware for decoding and playback.

Satellite radio may be an effective strategy for disseminating motorist or traveler information, although its use requires a monthly subscription fee and special radio hardware in the vehicle. XM Radio estimates that 50% of the automotive fleet will be equipped with satellite radio hardware by 2009.

Key characteristics of satellite radio are:

- Special in-vehicle hardware is required to receive broadcasts.
- Automakers are beginning to incorporate satellite radio receiver hardware into new vehicles.
- Hundreds of programs are available on satellite radio.
- A monthly subscription fee is required to receive satellite radio.
- Satellite radio presently has 12 million listeners between the two services.
- Dedicated commercially prepared and frequently updated traffic reports are available for urban areas.
- Satellite radio offers nearly complete coverage of the continental US. The signal can however, be blocked by heavy rainfall, bridges and tall buildings.

The satellite radio providers are interested in providing traffic information, but have difficulty obtaining information for some of the smaller markets and rural communities. In addition, editing of the content is done so that the broadcast is relevant to the largest number of commuters across the market. As a result, urban traffic problems and severe problems with intercity interstates in a given radio market area get the most coverage.

Working with the satellite radio traffic information providers (Navteq and traffic.com) to encourage them to disseminate traffic information for major rural interstate incidents or weather events may have some merit.

6.2 ACQUIRING INFORMATION FOR HAR SYSTEMS

Rural roadways have few sources of information that can be used to provide real-time information for broadcast on HAR systems, or for display on dynamic message signs. DOTs seek to overcome these challenges using several means:

- Eyewitness reports: Radio reports from DOT agency workers and construction contractors describing road conditions and closures.
- Reports from reliable sources: In the California Highway Patrol’s computer-aided dispatch system, all calls from a mobile telephone to 911 are answered by a CHP dispatcher. This information is then filtered and made available to the public and the traffic reporting media. Arizona’s DPS CAD highway patrol reports are used in a similar manner; a DPS console is available at ADOT’s Phoenix TOC.
- Localized sensing systems: The fog warning system on Interstate 5 in central California uses visibility sensors to directly activate signage and warning systems.
- An advanced HAR application with temperature and precipitation sensors is being developed, to automatically broadcast winter driving condition advisories.
- Travel time measurement using locations of fleet vehicles, cell phones, toll tags or license plate matching at cordons.
- CCTV cameras.
- Traffic speed measurement sensors such as loops, microwave detectors, or passive acoustic detectors that are deployed at frequent intervals on urban and semi-urban freeway corridors.

6.2.1 Computer-Aided Dispatch Systems

It is a practice of the California Highway Patrol to make filtered reports of all calls and incidents affecting traffic available to the public and to commercial traffic reporters via the web. Advantages of this approach include:

- Completeness of the incident database.
- Nearly all incidents are reported to CHP using cell phones.
- Applicability to both rural and urban environments.
- No field infrastructure to deploy and maintain.

6.2.2 Traffic Reporting Media

Nearly all traffic information that is broadcast or disseminated by commercial radio stations or traveler information services is collected by professional traffic reporting services. These services obtain their information from multiple sources including state DOTs and law enforcement agencies. Sources used by traffic reporting media include:

- Aircraft: traffic reporters will fly certain routes during congested times to provide eyewitness reports.
- Tipsters: individuals recruited by the traffic reporters to call in and report road conditions.
- Official data sources such as az511.com and similar sites compiled through DOT-owned sensor networks and reports from highway workers.
- Law enforcement data sources, including regular telephone contact with dispatchers, public information officers and on-duty officers.
- Filtered computer-aided dispatch system interfaces as operated by some law enforcement agencies.

During peak hours traffic reporters face the challenge of filtering and organizing massive amounts of information into an interesting and relevant traffic report for the geographic area served by the radio station or traveler information service. The traffic report must be presented in a compelling format, with a radio-trained voice, and it must have a fixed duration to fit into the radio station's format. During peak hours only the most severe or important incidents are presented in the reports that radio listeners hear. For example, 620 KTAR in Phoenix provides traffic updates every ten minutes during peak traffic hours, with the spots typically lasting 60 seconds. The traffic update cycle and duration will vary from station to station.

During late night hours, if radio stations elect to carry traffic reports, traffic reporters may need to find something to report to fill their time slot. At these times minor incidents, such as a stalled vehicle on a shoulder, may be reported.

Metro Networks/Shadow Broadcast Services is the single largest traffic information gathering and reporting operation in the world. Radio station clients of either Metro or Shadow are tapped into a network of over 2,000 reporters, 65 fixed-wing aircraft, 35 helicopters, and thousands of traffic cameras, reporting through 65 operation centers located in every major city. Over 100 million people hear traffic reports generated by Metro Networks/Shadow Broadcast Services on 2,200 affiliated radio stations.

Other providers of this service include traffic.com and Navteq. Traffic.com specializes in delivering free (advertiser-supported) traffic reports for personal computers and cell phones. Navteq is a digital mapping firm that provides route guidance and navigation services; they offer a feature that overlays real-time traffic data on its maps.

7. MOTORIST ASSIST PATROLS: STATE OF THE PRACTICE

This chapter discusses business strategies and operations for motorist assist patrols (MAP) in rural Arizona. ADOT experience with this service in rural Arizona was fairly limited, although a rural MAP is currently operating on US 93 in the Kingman District. ADOT also has a MAP towing program operating in Tucson for the I-10 Widening Project, but its applications to a rural setting are limited. Motorist assist operations for several other jurisdictions or states are also discussed for comparison purposes. Because these services typically operate primarily in high traffic-volume urban areas, the discussion includes certain well-developed urban programs throughout the nation.

Motorist Assist Patrols may be operated by law enforcement agencies or DOTs or their contractors. Examples of all three types of MAP were found in Arizona:

- US-93 rural: operated by a contractor for ADOT.
- I-10 Tucson urban: operated by a contractor for ADOT.
- Flagstaff and Prescott rural areas: operated by volunteers for DPS.
- Metro Phoenix freeway system: operated by DPS using non-sworn state employees with funding contributed by ADOT.

Several types of assistance and response services in use across the nation were identified:

- Formal Motorist Assist Patrols.
- Informal Motorist Assist Patrols.
- Volunteer Motorist Assist Patrols.
- Emergency Tow Services.
- Incident Management Teams.

Quick clearance laws are also discussed in this section, as these laws may enable certain actions as may be appropriate to reduce congestion and reopen roadways after incidents.

7.1 MOTORIST ASSIST PATROL NEEDS

Currently in Arizona, motorist assistance is provided through the following means:

- Informally, in the course of DPS officers' and ADOT workers' duties.
- Through an urban Freeway Service Patrol program operated by DPS in Phoenix.
- Through varying statewide service patrol programs sponsored by individual ADOT and DPS districts, which use either paid or volunteer staffing.

Among all of the DPS highway patrol officers and related motorist assist programs statewide, nearly 47,000 hours of assistance were given to some 135,000 motorists in Fiscal Year 2006; in FY 2005, DPS personnel assisted 143,000 motorists in Arizona.

ADOT staff described several potential needs for special motorist assist services during the stakeholder interview process. Generally, ADOT's needs for special motorist assist services would be on major construction projects where there is a significant reduction in capacity, such as recent work on the US 93 corridor, the ongoing I-10 Widening Project in Tucson, or for the planned I-40 improvements near Flagstaff. Special motorist assist patrol services may also be useful during winter storms or other severe weather on I-40.

A "quick clearance" law to rapidly reopen the roadway after incidents was also cited as being of value. Such laws require vehicles with minor damage to be moved as soon as possible, and empower state forces to move more seriously damaged vehicles and cargos from the roadway, to improve safety and access at the scene. An Arizona quick clearance law (ARS 28-674) was passed in 2001, but still was identified in some District interviews as an ADOT need, as well as a concern for other incident response partners. More clear guidance on this capability would benefit rural highway workers that respond to serious incidents, to resolve any uncertainty about opening lanes through accident scenes.

7.2 INFORMAL MOTORIST ASSIST PATROL SERVICES

Informal motorist assist patrol services are common in all rural locations. The primary objective of this service is to help stranded motorists. This service simply involves highway maintenance workers and law enforcement officers stopping at disabled vehicles and incident scenes that have been reported by other motorists, or where an assistance callout was directed from operator dispatch. The worker or officer on the scene provides aid with whatever resources may be on hand. For example, an ADOT worker may offer a gallon of fuel or a DPS officer may volunteer to change a tire. If the individual on-scene cannot render sufficient aid, he or she will call for an appropriate response by a third party such as a commercial tow service or auto club, or, in the event of an incident, may call law enforcement and EMS. Advantages of this approach include:

- Little or no capital or operations costs outside of normal agency budgets.
- Large number of potential responders.
- Common service normally provided in rural areas.

Disadvantages of this approach include:

- Unpredictable response times.
- Limited tools and equipment on-hand to render aid.
- Some responders may not have specific training to provide aid.
- Aid may not be available when responders have higher priority duties (e.g., snowplowing or law enforcement).
- Due to the informal nature of this service no statistics are maintained.

There are no clearly identifiable costs associated with these informal services. However, some opportunity costs may exist. For example, highway patrol officers cannot be performing law enforcement duties while rendering motorist assistance. Both ADOT and DPS forces in their normal duties will do welfare checks and provide limited assistance whenever their formal duties are not impacted.

7.3 VOLUNTEER MOTORIST ASSIST PATROLS

This section describes the operations and business strategies for the Arizona DPS Volunteer Motorist Assist Patrol, the Nebraska State Patrol Highway Angels, and the City of Phoenix Motorist Assist Program. The Phoenix program is an example of a locally-operated assistance patrol. There are numerous other city-operated motorist assist programs both in Arizona and out-of-state.

7.3.1 Arizona DPS Volunteer Motorist Assist Patrol Program

The Arizona DPS operates volunteer-staffed motorist assist patrols through the Flagstaff and Prescott Districts, as the Civilian Reserve rural service patrol. The primary purpose of these services is to get travelers back on the road or to arrange for further aid, if the motorist-assist driver cannot resolve the problem. DPS vehicles (Figure 15) are used to render aid, and are equipped with basic motorist assistance tools including:

- Warning Beacons.
- Two-way DPS radios.
- Tire Changing Tools.
- Jumper cables.
- Fuel.
- Water.

Figure 15. DPS Motorist Assist Patrol Vehicles

The largest contingent operates out of District 12 (Prescott) which has six members in the program; Flagstaff (District 2) has an additional two members. Vehicles for this program have “Freeway Service Patrol” and “Highway Patrol” markings. The hours of operation of this program are somewhat irregular, and are heavily dependent upon the availability of volunteers. Some of the DPS rural MAP operator roles include:

- Assist to inflate and change tires.
- Request tow vehicles for the operator.
- Provide tools to make minor repairs.
- Remove roadway debris.
- Remove vehicles from unsafe locations.
- Assist officers at collision scenes, road and ramp closures.
- Assist as directed with DUI and other Task Force details.
- Provide information and directions.

In 2006 the six civilian reserve volunteers in the DPS Prescott district performed 1,364 hours of service, assisting 231 motorists and dealing with 42 abandoned vehicles. For the first half of 2007, these volunteers performed 485 hours of service, assisting 231 motorists and handling 65 abandoned vehicles.[32] Two volunteers in the Flagstaff area performed 216 hours of service over the same periods, covering about 5,000 miles total.[33]

7.3.2 Nebraska Highway Angels

The Nebraska State Patrol's motorist service patrol was named "Highway Angels" by the public. Volunteer drivers staff motorist assist patrol vans operating through a public-private partnership. The program receives grant funding for tools and equipment through the Nebraska Office of Highway Safety, and State Farm Insurance donated funds to procure some of the motorist assist vehicles. "This is an outstanding example of a public-private partnership that maximizes State Patrol resources and certainly benefits our citizens and visitors who travel through Nebraska," said Governor Mike Johanns.[34]

The program operates on Sunday nights and on weekdays during the rush hours of 6:00 AM to 10:00 AM, and 3:00 PM to 7:00 PM. The area of coverage is approximately 85 centerline miles of roadway, consisting of both urban and semi-rural highways in three regions: Omaha, Lincoln, and Grand Island. The following duties are performed by the Highway Angels volunteers:

- Servicing disabled vehicles with fuel and/or fluids.
- Changing flat tires or arranging tows.
- Providing jump starts or transportation.
- Clearing debris from the driving lanes.
- Tagging abandoned vehicles.

Volunteers receive one day of training by the Nebraska State Patrol prior to entering volunteer service. The program currently has 27 volunteers, many of whom have dedicated more than 1,000 hours of service to the program. The volunteers have covered 500,000 miles and assisted more than 20,000 stranded and lost motorists since the program began in 1998. In 2005, volunteers in the Omaha program alone made a total of 5,284 contacts and devoted 6,802 hours to the program.[35]

Stated benefits of the NSP program include:

- Provide a variety of services to motorists with disabled vehicles.
- Reduce traffic crashes by removing hazardous objects from the roadway.
- Relieve traffic congestion by solving problems that cause backups and delays.
- Free police officers to concentrate on more serious enforcement situations.

7.3.3 City of Phoenix Police Department Motorist Assist Program

In Phoenix, Arizona, the MAP program has uniformed civilian volunteers who assist motorists who have vehicle problems. Assistance includes pushing vehicles, starting vehicles, opening vehicle doors (lockout), providing fuel, air, or water, assisting with changing a tire, arranging transportation, or giving other reasonably required aid to temporarily stranded motorists.

Volunteers also work closely with sworn police personnel and may be called to vehicle crash scenes for traffic control or other duties. There are currently 15 volunteers providing more than 500 hours of service each month.[36]

Advantages of this volunteer motorist assist patrol program include:

- No labor costs.
- Trained responders.
- More predictable hours of operation and response times than informal programs.
- Potential for public-private partnerships for cost sharing.
- May free up law enforcement officers for other duties.

Disadvantages of this approach include:

- Recruitment of sufficient qualified volunteers is a challenge.
- Agency staff needed to serve as trainers and volunteer coordinators.
- Erratic volunteer schedules.

The capital cost for a basic motorist assist patrol van with tools is $20,000. Vehicle operating costs and fuel are normally absorbed in the sponsoring agency's fleet budget.

7.3.4 Other Volunteer Motorist Assist Programs

There are also several volunteer motorist assist patrols operated by Police Departments in other Arizona cities, including:

- Chandler
- Tempe
- Paradise Valley
- Prescott Valley

Similar programs operate in other states as well. One example is Lakewood, Colorado. The business plans, duties and operational guidelines are generally similar for all of these city-sponsored volunteer programs.

7.4 PROFESSIONAL RURAL MOTORIST ASSIST PATROLS

Professionally-managed MAP programs are also operating in rural settings across the nation. These services differ significantly from the professional urban MAPs, described later. Typically the operators of these programs are designated law enforcement officers, state DOT maintenance technicians, or private contractors.

The primary roles of professional MAP programs in a rural setting include:

- Rendering aid to motorists.
- Rapidly clearing any obstructions where sight distance is limited.
- Minimizing the potential for secondary collisions in the queue.

Key advantages of professional Rural Motorist Assist Programs include:

- Defined service areas and hours.
- Prevention of secondary crashes through reduction of incident duration.
- Prevention of secondary crashes through deployment of traffic control measures.
- Providing real-time information to law enforcement dispatchers.
- Freeing-up sworn law enforcement officers for higher priority duties.

The primary disadvantage of a professional MAP in a rural setting is the high cost of establishing and maintaining an effective program on a remote rural corridor with few traveler amenities. These programs require substantial funding for their fixed costs, vehicles and staffing. As a result, professionally-staffed fulltime MAPs may be impractical in rural areas. Still, contracted motorist assist patrols can be useful in specific applications such as construction projects, if they can be budgeted at the outset.

The following sections summarize the attributes of two current programs:

- The US 93 Motorist Assist Patrol – an Arizona rural patrol sponsored by ADOT and operated by a contractor.
- The Eisenhower Tunnel Patrol, operated by Colorado DOT using state employees.

7.4.1 US-93 Motorist Assist Program

This is ADOT's own rural motorist assist program. It operates on US 93 south of Kingman, Arizona, from 10:00 PM to 6:00 AM in an active construction zone. The official coverage of the program is approximately 25 miles. Depending on events that the operator becomes aware of, the patrol route may extend to about 60 miles in length.

This program is funded through the highway construction project's contract. The Kingman District has operated one patrol unit on consecutive construction contracts more or less continuously since 2000. The construction contractor is responsible for providing one motorist assist truck with a driver for the duration of the project, and for maintenance of the MAP vehicle. This program is a true MAP in that it does not offer towing.

Because the US 93 MAP vehicle is not state-owned, it has not been possible to install a DPS radio in the vehicle. However, the vehicle operator uses a scanner to listen to DPS communications, and can easily contact DPS via a cellular telephone call to the Phoenix TOC as long as he is in an area with cellular coverage. In general, the MAP operator has succeeded at dovetailing ADOT's MAP duties and emphasis, with those of DPS. Also, the operator's familiarity with truck drivers in the area, and use of Citizen's Band Radio to communicate with them, is an invaluable asset and a boost to this patrol's success.

The Kingman District uses a two-wheel drive pickup truck. A few of the key emergency equipment items include a front push bumper, spotlights, digital cell phone, camera, flashlights, jumper cables, fuel, tools, tow rope, flares, ABC- and D-class fire extinguishers, a three-ton jack, a first aid kit and accessories, citizens band radio, ADOT radio, multichannel mobile scanner, traffic cones, radiator coolant, and drinking water.

The one US 93 MAP operator has, on average, logged about 120 assists per year. These assists include direct aid to motorists in trouble, as well as removal of roadway obstacles and other activities. The MAP represents less than 1% of the total project construction cost. The current MAP bid item totaled $150,000 for a patrol to run full time (eight hours) during weekday nights during a 30-month time frame.

7.4.2 Eisenhower Tunnel Motorist Assist Patrol

The Colorado Department of Transportation operates a motorist assist patrol for the Eisenhower Tunnel on Interstate 70 between Vail and Denver, Colorado.[37]

With a coverage length of approximately 1.7 miles, the traffic management facility is staffed 24 hours a day, with full CCTV monitoring of the tunnel roadways. The current staffing level is set at 49 full-time employees.

One of several on-duty CDOT employees operating a state-owned wrecker will assist any stranded motorists within the twin tunnels, 24 hours a day. This rural motorist assist patrol program shares many of the characteristics with informal motorist assist programs (e.g., costs are absorbed into overall operations and maintenance budgets, and the lack of any dedicated staff devoted exclusively to motorist assist functions).

7.5 PROFESSIONAL URBAN MOTORIST ASSIST PATROLS

There are numerous examples of professionally-operated motorist assist programs around the country. In general these programs operate in congested or urbanized areas, with a wider range of goals, such as congestion reduction and air quality. Some professional MAP services also provide emergency towing services. These programs may be operated by law enforcement agencies, DOTs, or contractors. The purposes of urban-area motorist assist programs often include:

- Rendering aid to motorists.
- Mitigating congestion, reducing fuel consumption and improving air quality by rapidly clearing capacity-reducing incidents.
- Eliminating or reducing non-recurrent congestion by removing debris.
- Minimizing the potential for secondary collisions in the queue.
- Freeing-up sworn law enforcement officers for higher priority duties.
- Maximizing the effectiveness of the freeway transportation system.

Key advantages of professional Urban Motorist Assist Programs include:

- Defined service areas and hours.
- Congestion mitigation – delay reduction.
- Air quality improvement through congestion mitigation.
- Reductions in fuel consumption through congestion mitigation.
- Prevention of secondary crashes through reduction of incident duration.
- Prevention of secondary crashes through deployment of traffic control measures.
- Providing real-time information to law enforcement dispatchers.

The primary disadvantage of a professional urban MAP service is its relatively high cost, which requires a substantial tax base to fund. An example of the costs for an urban MAP is California's program, which costs approximately $130,000 per tow truck per year. Services established in dense urban settings can see a high benefit/cost ratio, as the number of beneficiaries in a metropolitan area will far outnumber those in a rural area.

The following sections summarize the attributes of several significant programs:

- Arizona DPS Freeway Service Patrol.
- Los Angeles Regional Freeway Service Patrol
- Florida Road Rangers.

7.5.1 Arizona DPS Freeway Service Patrol (FSP)

In 2001, overworked Department of Public Safety Highway Patrol officers made 63,380 contacts with stranded motorists in just the Phoenix metropolitan area. Calls for roadside assistance services draw greatly on the officers' time, resulting in less availability for traffic enforcement and collision reduction programs. This steadily increasing workload led to the creation of the Arizona DPS Freeway Service Patrol in 2001.

This urban FSP is a professionally staffed service patrol program that uses DPS civilian employees who are not sworn law officers to render motorist assistance. The program is funded through a partnership of ADOT, Arizona DPS, AAA of Arizona and the Maricopa Association of Governments. This service patrol covers the growing freeway system in the metropolitan Phoenix area and operates 18 hours a day, seven days a week, typically with well-equipped FSP vans.

This DPS program is a true service patrol and does not offer towing. Key duties include:

- Locating and assisting stranded motorists.
- Removing road hazards.
- Diagnosing minor vehicle problems.
- Making minor repairs.
- Removing roadway debris.
- Calling for tow truck assistance.
- Assisting officers at collision scenes and at closure points.

From July 1, 2006 to June 30, 2007, the ten DPS Freeway Service Patrol team members working in the Phoenix metropolitan region performed 13,590 hours of patrolling, while driving 355,220 miles in the process. They performed 13,912 roadside assists, and they responded to 42,040 calls for services.[38] This program may also be a good concept for the Tucson freeway system, as the area of influence for that city expands each year.

7.5.2 Los Angeles Regional Freeway Service Patrol

The Los Angeles Basin Freeway Service Patrol[39] is an urban patrol operated by nearly fifty independent contractors, and funded by a partnership of public entities including Caltrans, the California Highway Patrol and the Los Angeles County Metropolitan Transportation Authority. The Los Angeles program was the first freeway service patrol, and is considered a major success. The California Highway Patrol has implemented these freeway service programs in ten large and mid-sized urbanized areas.

This FSP operates Monday through Friday during peak commute hours, and all day in pre-designated freeway construction zones. The patrol has 300 tow trucks on duty throughout the state. The program includes both a service patrol and an emergency towing component. Statewide each year, the program assists approximately 600,000 motorists in ten metropolitan areas at a cost of nearly $40 million. A local match of 25% is required for the program to operate. In urban areas, the local match is substantially higher, resulting in an even $20 million / $20 million split between local and Caltrans funding. Based on the number of assists and the program funding level, the cost of an average FSP assist is approximately $67; a recent study of the ten regional California programs showed a benefit/cost ratio of 8.3:1. In the Los Angeles Basin metropolitan area, the 145 tow trucks on duty service more than 400 centerline-miles of urban freeways. Approximately 325,000 motorists are assisted annually in this region alone.[40]

7.5.3 The Florida Road Rangers

The Florida Road Rangers[41] program is an urban freeway service patrol sponsored by the Florida Department of Transportation (FDOT) and operated by multiple contractors. This is a true motorist assist program in that towing is not provided. The program's mission is to provide free highway assistance services during incidents to reduce delay and improve safety for the motoring public and responders.

The Florida FSP is a major program in six of the seven FDOT districts, with contractors operating 111 vehicles on 1,025 centerline miles as of July 2006. The number of assists (see Table 9) has steadily climbed in nearly every year since the program began in 1999.

Table 9. Florida Road Ranger Motorist Assist Statistics

Year	Number of Assists
2006	277,537
2005	298,776
2004	342,895
2003	316,883
2002	279,525
2001	198,372
2000	112,000

The Florida service patrol was initially used for the management of vehicle incidents in construction zones. The program has since expanded to respond to all type of incidents and has become one of the most effective elements of FDOT's incident management program. Costs for this FSP were $13.6 million in 2004, as reported by the University of South Florida for FDOT, and the overall benefit/cost ratio for the Florida Road Ranger program is 25.8:1.[42] Initial funding for the program, in Jacksonville, was $468,000.[43] The stated benefits of this program [44] include:

- Reduction of accidents.
- Reduced delays (1 million hours in 2004).
- Fuel savings (1.7 million gallons in 2004).
- Reduction of incident duration by assisting the Florida Highway Patrol.
- Assistance to disabled or stranded motorists.
- Removal of road debris.

7.6 EMERGENCY TOWING SERVICES

Both the Chicago Service Patrol and the Los Angles Freeway Service Patrol programs provide emergency towing services. The towing services are urban freeway models with high benefit/cost ratios. The Los Angeles program was described above.

Chicago's Emergency Traffic Patrol (ETP) program[45] is operated by the Illinois Department of Transportation (IDOT); this program is among the Nation's oldest. The ETP began in 1960 with several pickup trucks manned by Illinois DOT employees operating during peak periods. This is the most broadly scoped of the incident response programs surveyed. In addition to the typical duties of a service patrol, the Chicago ETP also performs the following duties:

- Heavy vehicle towing (up to 60 tons).
- Spilled load clean-up.
- First-Responder duties at crash scenes.
- Assist in extrication of injured.
- Assist State Police with traffic control and detours.

The program employs 76 individuals and operates a fleet of 35 medium duty tow trucks, 2 heavy duty wreckers, and 11 pickup trucks. The ETP operates 24 hours per day to patrol 100 centerline miles of freeways in the Chicago area. Drivers are limited to spending no more than 20 minutes per vehicle to make minor repairs. The towing services provided are limited to moving a vehicle to a shoulder, accident investigation site, or a nearby freeway exit. The ETP will contact the State Police or motor clubs to render further assistance when needed.

A key feature of the ETP tow trucks is the ability to hook-up and tow a vehicle without leaving the cab of the truck. Communications equipment in the vehicles includes fire and police radios, and they are equipped with an extensive collection of tools. The annual budget for the program is between $3.5 and $4 million; the ETP claims a benefit/cost ratio of 17:1. The Chicago ETP provides approximately 100,000 expressway motorist assists each year and enjoys strong public support, receiving approximately 900 thank-you letters annually.

7.7 MAJOR INCIDENT TRAFFIC MANAGEMENT TEAMS

These specialized teams operate differently than service patrols. The function of these teams is to respond to major incidents, assist in traffic control, give detour information, and reduce the likelihood of secondary collisions at the end of a queue. These teams do not provide direct assistance to stranded motorists, but have communications equipment to arrange for a tow. Caltrans, for example, defines a major incident that warrants a traffic management team response as an incident that blocks two or more lanes for two or more hours. These teams are primarily deployed in urban areas.

The ADOT ALERT (Arizona Local Emergency Response Team) program is a designated team that responds to incidents on freeways in the Phoenix metropolitan area. There are eight ALERT response trucks manned by on-call response technicians, four of whom reside in the eastern part of metro Phoenix, and four in the west-side communities. They cover 450 miles of roadway, on a 24/7 basis.

ALERT's primary tasks include assisting DPS with short-term incident traffic control, coordinating traffic-related issues with an on-site command center, providing minimal signing for detour routes, and coordinating the use of electronic message signs with the Traffic Operations Center. For incidents where one or more lanes are closed for one or more hours, DPS may request ALERT personnel presence to address traffic concerns.

The ALERT Team provides safety support to ADOT Maintenance during longer duration incidents, such as cleaning chemical spills and clearing crash sites, and may also coordinate with surrounding jurisdictions, such as Maricopa County DOT, to respond to major incidents. ALERT may also be dispatched by ADOT field supervisors or by the TOC, based on the type of incident, or verification of an incident on freeway cameras.

Over the past six years, ALERT has averaged 15 major incident calls per month, or 185 each year. The average response time has ranged from 22 to just 18 minutes in 2006-07. The six-year average response time is 19 minutes, and the average incident duration has been 3 hours, 18 minutes.[46] The overall incident duration is heavily influenced by the investigating police agency, where ALERT offers a supporting role in incident response.

The advantages of a broadly scoped DOT incident management program include:

- An ability to rapidly reopen freeway lanes.
- Ready availability of heavy recovery equipment at incident scenes.
- Ability to assist with a broad range of incident management duties.

The primary disadvantage of a program of this nature is the relatively high cost and extensive training requirements for the staff. The Department plans to add two more members and vehicles to the ALERT program as funding becomes available. As the regional freeways grow, ADOT recognizes the need the expand ALERT when possible. Costs of this program are absorbed in the Phoenix District roadway maintenance budget.

7.8 BUSINESS PRACTICES AND OPERATIONAL CONSIDERATIONS

The sample business practices for MAP programs, listed below, are based on Standard Operating Procedures for the Los Angeles Freeway Service Patrol.[47] These practices clearly define the scope of required and prohibited actions of service patrol staff.

7.8.1 Duty to Use Reasonable Care

Once a MAP operator establishes any contact with a motorist, the operator has established a responsibility to use a reasonable amount of care in rendering services. An operator shall not place a motorist, passenger, or pedestrian in a position of foreseeable danger from either traffic or other potentially hazardous factors after contact has been made. It is the responsibility of the operator not to leave the motorist in a worse situation than that which existed before contact was made. This includes not leaving a motorist stranded at a drop location where the safety of the motorist may be compromised. It is the operator's responsibility to ensure that help is en route or that the motorist has access to additional public services.

Center dividers, gore points and narrow shoulders are always considered dangerous locations. Once an operator establishes contact with a motorist in any situation that may be dangerous, it is that operator's responsibility to stay with the motorist until relieved by law enforcement, another tow company or until the motorist is moved to a safer location. If a motorist refuses service or if the operator leaves the motorist, the operator must inform corresponding law enforcement and advise the motorist of potential hazards.

7.8.2 Statistical Data Collection

MAP personnel collect activity information on a motorist assist form that can be coded for statistical analysis. The data and questions on this form are used to document key aspects of each assist, which is collected for overall assessment of MAP operations:

- Date.
- Operator ID.
- Time Arrived and Time Departed.
- Patrol Area.
- Disabled Vehicle License Number.
- Location of Disabled Vehicle (Route Number and MP).
- Reason for Assist.
- Type of Vehicle Assisted?
- Motorist Wait Time for Arrival.
- Location Disabled Vehicle Towed To.
- Who Towed the Disabled Vehicle?
- Did the Motorist Receive or Request Additional Assistance?

7.8.3 Performance Incentives and Penalties

The FSP Performance Measures Incentive Program used in Los Angeles is intended to recognize contractors/operators who maintain an exemplary operational performance record. Factors considered in awarding performance incentives are shown in Table 10.

Table 10. MAP Operator Performance Measures of Effectiveness

Contractor Meeting Attendance	Driver Proficiency Testing
Cursory CHP Driver Inspection	On-Time at Start of Beat
Assist Data Submission	Mechanical Reliability
Beat Assist Rate	Driver Attendance
Complaint Investigation	Truck In-Service Reliability

8. INFORMATION SHARING:
STATE OF THE PRACTICE

A key issue for the Department is more effective global dissemination of accurate information about current and future ITS deployments, and about new developments, opportunities and benefits in this field. However, during the stakeholder interviews, the lack of time to learn about ITS deployments and innovations was frequently cited as a problem, due to multiple responsibilities for many other duties and tasks.

ADOT's ITS research field activities and ATRC project reports were viewed as a useful reource to bring more technology awareness to personnel in the Districts. These projects provide opportunities for the Districts to express their concerns and needs, as well as to gather with other ITS stakeholders to discuss ideas and share information.

8.1 ITS INFORMATION SHARING RESOURCES

There are many tools and educational resources available to the ITS practitioner; training materials with specific ITS content and relevant conferences are offered by:

- ITS America
- ITS Arizona
- The International Municipal Signal Association (IMSA)
- The Institute of Transportation Engineers (ITE)
- The Consortium for ITS Training and Education (CITE)

Each of the noted professional organizations holds regular conferences and meetings. ITS Arizona holds an annual conference in the fall in the Phoenix area. Quarterly meetings are also held at a variety of locations including Flagstaff, Prescott, and Tucson.

IMSA offers regular training and a joint annual conference with ITE each year in the spring, in Phoenix. IMSA training provides the core technical skills which serve as a foundation for safe ITS implementation. Training sessions offered include work zone safety and traffic signals.

ITE also provides training via *webinars* in traffic-engineering–related topics that have some crossover into the ITS field. Webinars are seminars conducted over the internet, similar to teleconferencing, using an interactive presentation via video.

CITE is a unique organization of universities and industry associations focused on providing comprehensive advanced transportation training and education in the ITS field. CITE offers over thirty interactive web-based courses available to anyone, including the ADOT rural ITS practitioner. The courses can be combined to earn advanced transportation certificates and continuing education units. The cost of CITE courses is competitive with University classes. Courses offered include topics such as:

- Fundamentals of ITS and Traffic Management.
- ITS Applications and Management.

- ITS Project Management & ITS Systems.
- Advanced Systems Engineering for Transportation Projects.
- Advanced Telecommunications Technology.
- Fundamentals of Database Management Systems.
- Improving Highway Safety with ITS.
- Introduction to CVO/CVISN.
- Rural ITS.
- What's New in ITS.

8.1.1 Local Technical Assistance Program

ADOT maintains a library of video training presentations on both VHS and DVD formats through its Local Technical Assistance Program (LTAP). Courses are offered in a variety of topic areas such as winter maintenance, structures, surveying, traffic controls and heavy equipment operations. The programs normally consist of compilations of videos prepared by experts within different DOTs. For example, brief descriptions of the video content of the Winter Maintenance section of the Arizona library are provided below[48]:

- *Plow Power:* Illustrates safety and snow plowing techniques on city streets, at intersections, and in subdivisions.
- *Response to Winter:* Explains the policies and procedures of the Pennsylvania Department of Transportation winter operations to give the public a better understanding of how they prepare for and deliver winter services.
- *Sand and Salt Spreader Calibration:* Offers a guide for successful spreader calibration and explains the proper techniques and calculations.
- *Using Snow Plows on Motor Graders:* Instructs how to attach snow plows to the various brands of motor graders, and gives basic information on how to use plows to remove snow from roads.
- *White Gold:* Presents key aspects of snow fighting operations, and includes training, public relations, planning, salt/abrasive application. Illustrates a variety of equipment and plowing methods.
- *Snow Fighting from A to Z:* This three part video contains the Snow Fighters, Salt: The Best De-Icer, and Salt: the Essence of Life. Methods of application are thoroughly discussed.
- *Anatomy of a Winter Storm:* A depiction of the dangers and hardships that snowplow drivers and motorists encounter during a snow storm.

8.1.2 National Highway Institute Courses

The National Highway Institute offers a free ITS Distance-Learning Course through its web-based learning network**.** This course is offered through the University of California-Berkeley, an NHI partner, and offers instruction at the Web-based learning site based on two federal Professional Capacity-Building courses: "ITS and the Planning Process" and "Planning for Deployment of Regionally Integrated ITS." The site also includes information and examples specific to California. The general goal is to provide just-in-time training and support for mainstreaming ITS projects into the regular regional planning process. Unlike most training programs, there is no charge for this course.

The Federal Highway Administration is also sponsoring the development of training materials that focus on weather-related transportation issues; many of these session topics may be ideally suited to a rural environment. Examples of training resources being sponsored by the FHWA include:

- ITE Professional Development CD for Weather Management.
- AASHTO Anti-icing/RWIS Computer-based training.
- *Road Risk* DVD with The Weather Channel.
- NHI Course *Principles and Tools for Road Weather Management.*

8.1.3 Discussion: *Principles and Tools for Road Weather Management* NHI Course

This one day NHI course provides transportation professionals in highway maintenance and/or highway operations with training to develop tools and strategies for addressing weather-related operational problems. The course begins with an overview of the types of weather problems and their associated costs, as well as basic meteorology for non-meteorologists. Through this course, participants are exposed to various strategies for addressing road weather problems, including Road Weather Information Systems, and the development of crosscutting decision support systems to respond effectively to weather situations. In addition, road weather solutions unique to maintenance management, traffic management, traveler information, and emergency management are discussed.

Course organizers expect that, upon completion of the course, participants will be able to:

- Recognize the crosscutting impacts that weather has upon roadway operations.
- Identify the technical and institutional challenges of implementing road weather management strategies.
- Explain the range of effective and open solutions to the various types of weather for various management practices, i.e., maintenance, traffic, emergency, and safety management.
- Discuss the variety of operational tools and techniques available to the transportation community to deal with the impacts.

The cost of this course is $200 per person; the course can be hosted by ADOT with a minimum of 15 participants.

8.2 CONFERENCES

Conference resources that the FHWA is targeting to inform practitioners about Clarus and other federally backed initiatives include:

- AASHTO/FHWA Eastern Snow Expo.
- ITS America Annual Conference: "Weather Alley."
- Transportation Research Board (TRB) Annual Meetings.

Local non-ITS focused general purpose conferences can also be an excellent tool to expose a broad audience to highlights of ITS. Examples of relevant conferences are:

- The "Roads and Streets" annual conference, sponsored by the Arizona Chapter of the American Council of Engineering Companies (ACEC).
- The biennial ADOT Winter Maintenance Conference, sponsored by the Technical Training Group's Local Technical Assistance Program.

ADOT's LTAP organizes the Winter Maintenance Conference every other year at different high-elevation sites around Arizona. The conference offers broad winter-maintenance–related content, often including presentations on rural ITS technology. The conference is targeted to ADOT maintenance workers as well as their local-agency partners from around the state, including county, city, and tribal agencies. Approximately 200 people attended this event at Prescott in October 2006.[49]

This conference provides an opportunity for numerous agencies throughout Arizona to come together and share information regarding maintenance activities and experiences. Vendors also can relay information from their experiences with other agencies. ITS topic presentations should be considered for this event, to reach a broad audience at various levels of the highway maintenance organization.

As an example, at the 2006 Winter Maintenance Conference, L3 Communications Group displayed two snowplow driver training simulators housed in a mobile classroom trailer. This teaching tool is also used for training of Utah DOT snowplow operators. As of mid-2007, ADOT has acquired four snowplow simulators to train operators in northern and eastern Arizona. Researchers from Arizona State University are currently performing a series of studies for ADOT to determine the potential safety and efficiency benefits of further simulator training implementations.

8.3 INTERNAL ADOT MEETINGS

ADOT holds a number of peer-to-peer networking meetings that may provide a good multi-purpose platform to give a diverse staff more exposure to ITS, and ultimately to mainstream ITS for application on rural corridors. Examples of these conferences include the ADOT Maintenance Training Workshop (held in Tempe in late 2007), regular meetings of the ADOT District Engineers, meetings of the regional traffic engineers and signal technicians, and the Maintenance Servant Leadership Team (MSLT).

8.4 COMMERCIAL VEHICLE OPERATIONS MONITORING

ADOT's Motor Vehicle Division (MVD) maintains the ports of entry into the state, requiring permits for oversized vehicles traveling from outside of Arizona through the state, or to destinations within it. MVD works closely with federal and state agencies to ensure the safe movement of commercial vehicle traffic on Arizona highways. Their services include issuing permits, collecting commercial vehicle taxes, and performing a variety of commercial vehicle regulatory activities including the enforcement of laws defined by the Arizona Revised Statutes, and the Administrative Rules.[50]

The permitting process is computerized, and certain corridors are programmed as designated routes for oversized vehicles. Permits are categorized as either Class A or Class C, with excessive-size or -weight loads falling in the Class C category. In recent years the number of issued permits has jumped significantly, in some cases increasing almost 100 percent over the year before. Table 11 identifies the number of Class C permits issued for Arizona highways over for the past several years.[51]

Table 11. Class C Permits Issued by ADOT Since 2003

Year	# of Class C Permits Issued
2003	9,570
2004	7,648
2005	14,738
2006	14,223
2007	14,000+ (Estimated)

A significant challenge to the permitting process is the number of oversized loads originating internally within the state, going to other locations within the state borders. Oversized vehicles cause an estimated $12 to $53 million per year in uncompensated damages, with approximately 15 to 30 percent of vehicles operating in excess of legal weight limits.[52] These are costs to ADOT due to non-compliant vehicles traveling illegally without permits and causing significant damage to the state's highway infrastructure including bridges, signs, poles, mast arms, guardrails and other structures within ADOT right-of-way. Only if the offender is witnessed or caught does the state recoup costs; more typically, drivers that cause damage are not identified.

In order to offset highway road repair costs, the fees collected during the permitting process pay for administration costs and infrastructure upkeep. To help prevent highway infrastructure damage, ADOT-MVD conducts load audits on random vehicles using mobile weigh stations, with an annual budget of $6 million.

The primary reasons for applying ITS in the current ADOT permitting process include:

- Steady increases in permit requests have overburdened the agency's resources.
- Oversized loads that originate within Arizona are difficult to process and track.
- Multiple jurisdictions are typically involved, with differing rules and regulations.
- Oversize/overweight transport drivers may ignore assigned permit routings, if too long and circuitous, often resulting in significant damage to the roadway.
- High costs and delays in permitting are ultimately passed on to the consumer.

Currently, ADOT operational procedures are for MVD to provide various commercial vehicle enforcement services, and administer all permits. Individual oversized vehicles are provided escorts by the DPS if they do not already have privately-hired escorts. The purpose is to allow ADOT to issue oversize permits to qualified applicants for specific loads with exact dimensions and weights.

Based on the load dimensions, DPS and ADOT have developed route specific guidelines, and drivers are assigned a programmed route to the destination. Figure 16 details a typical route for oversized vehicles through the southern region in Arizona, identifying the additional mileage and travel time associated with the circuitous path.

Figure 16. Typical Oversized Vehicle Programmed Route on I-10

Most permits require escorts both in front of and behind each oversized load, and escort drivers must be certified. In each case, ADOT traffic and resident engineers are contacted to assess the oversized dimensions and weights, to confirm that the assigned route is appropriate. As oversized loads are common on Arizona roadways, this complex process occurs on a daily basis, several times a day, to the detriment of other tasks. ADOT MVD does not presently have any effective tracking mechanisms in place. The transportation industry actively discourages proactive oversight by regulatory agencies. Funding is limited for inspection sites, and is largely allocated to state ports of entry. Mobile enforcement requires inspection sites throughout the interior of the state to verify that programmed routes and bridge constraints are observed.

The issuance of Class C special-load permits is constrained by resources. MVD currently has a staff of only three responsible for coordination and tracking of oversized loads; ADOT Maintenance forces serve in a supporting role. This produces an additional strain on the existing operations of vehicle inspection sites. Verification processes are being streamlined to expedite movement of oversized loads, and an “Easy Class C” permit is being finalized for legislative approval. The agency goal is to have an established on-line system similar to the existing Class A permit process.

Supported by the Overdimensional Permits Advisory Council (ODPAC), Arizona Senate Bill 1218 was passed in 2006. This bill streamlined some permit requirements for local jurisdictions, defaulting to the state permit requirements if no local protocols are in place. Local jurisdictions are also to coordinate with ADOT on current regulations and corridor-specific issues; this may include counties, cities, federal lands agencies, and Native American reservations. The bill also established an escort certification program.

While SB 1218 addressed some concerns, others still remain, for which ITS may offer some potential relief from ADOT’s permitting challenges. The primary need is the ability to track individual oversized vehicles throughout the state based on their weight, and their height, width and length dimensions. A statewide database is needed for all oversized vehicle travel. If properly maintained and updated, ADOT staff can better identify potential conflicts between vehicle dimensions and infrastructure constraints before damage occurs, potentially saving millions of dollars of bridge and highway reconstruction. Also, individual vehicles can be identified if specific damage to ADOT’s infrastructure is discovered during a targeted time period.

PART THREE - IMPLEMENTATION PLANS

9. ITS MAINTENANCE IMPLEMENTATION PLAN

The primary focus area identified by the ITS stakeholders for highest priority is deployed systems maintenance. This chapter details the proposed plan that integrates numerous state-of-the-practice deployment concepts for ITS maintenance into a set of project implementation recommendations that address both project goals and stakeholder needs.

Each concept discussion includes an engineer's opinion of probable cost over a five-year life cycle based on capital expenditures, on-going operations and maintenance costs, recommended staffing, ongoing utility costs and/or designated consultant fees. The most significant potential concepts to enhance ITS maintenance statewide are:

- Third-Party ITS Maintenance Contracting.
- Truck Ramp Monitoring / ITS-Instrumented Ramps.
- Improved Statewide Cellular Coverage.
- Additional DMS Construction.

9.1 THIRD-PARTY ITS OPERATIONS AND MAINTENANCE

ITS infrastructure maintenance was of primary interest to the district stakeholders during the interview process. Many districts acknowledged funding and resource challenges for maintaining the deployed ITS devices. Funding and staffing for effective ITS device maintenance typically did not exist at the District level outside of the Phoenix metro area.

Concept Benefits and Challenges
Benefits of this concept include more consistent allocation of appropriate resources to ITS infrastructure operations and maintenance, where currently all of the Districts are challenged with this task. The concept also applies the expertise of technology-proficient contractors to see that the tasks are accomplished efficiently and thoroughly. Challenges for this concept include contracting with a vendor capable of servicing multiple regions with different needs.

Because Arizona is such a large state, requiring a vendor to service ADOT's rural ITS maintenance needs would involve additional time spent on commuting, and may necessitate work performed in isolated areas. In many rural areas, maintenance contractors with the requisite skill may not be available or companies will demand a premium fee to maintain rural ITS devices, due to the travel times involved.

Concept Implementation Recommendations and Cost Breakdown
Through project discussions with the stakeholders and the TAC, it is clear that finding legislative support for adequate and effective ITS operations and maintenance has been a major challenge for the Districts. It is recommended that both ITS operations and maintenance needs be met with third-party contracting for total ITS deployment

statewide. This would include all existing deployment and any ITS device programming constructed for the duration of the contract.

Third-party contracting addresses the major project goal for identifying and addressing statewide operations and maintenance issues, and was cited as a priority by all of the Districts. Designated contractors could be assigned for each of the three regions: Flagstaff in the northern region, Phoenix for the central metropolitan region, and Tucson for the southern region. On-call service contracts to be established with the contractors would include:

- Routine Operations.
- Routine Maintenance.
- First Responder Troubleshooting.
- ITS Device Parts Inventory Storage and Oversight.

The opinion of cost for this concept is $200,000 for maintaining on-call contracts for operations and maintenance in all three regions for each year, for a total commitment of $1,000,000 over five years.

9.2 TRUCK ESCAPE RAMP MONITORING

Another promising ITS concept is the instrumentation of the seven existing truck escape ramps that currently are not being monitored. Implementation goals for individual truck escape ramps would include:

- Detection of incursions.
- Activation of warning signs.
- Provisions for email alerts.
- Provisions for snapshot images.

Once the presence of a vehicle is detected, maintenance technicians will be alerted through emails or a paging system, accompanied by snapshot images of the intrusion. Shoulder-mounted warning signs are automatically activated to alert other roadway users that the ramp is occupied. Alerted technicians would review the conditions and either deploy adequate resources to restore the ramps to original, undisturbed conditions, or reset the ramp sensors if a false intrusion warning occurred.

Concept Benefits and Challenges

Monitoring of the truck escape ramps allows the Districts to maintain a higher level of safety, where the frequency of ramp utilization will create safety concerns if a truck has not yet been removed from the ramp when it is again needed. Monitoring the ramps also prevents guesswork by maintenance technicians, and alerts them to immediate demands for attention at a site. Challenges for this concept include establishing communications and power, where the ramps are in obscuring terrain and isolated locations.

Concept Implementation and Cost Breakdowns

It is recommended that the project include the establishment of criteria for the instrumentation of ramps, such that liability concerns are a non-factor. This would be considered the first phase of the project where, once the criteria are established, each truck escape ramp would be evaluated for ITS deployment. This concept was identified through field interviews.

Locations of truck escape ramps that are currently not instrumented with intrusion detection are shown in Figure 17:

- I-17, MP 284, Northbound.
- I-17, MP 300, Southbound.
- SR 77, MP 156, Westbound.
- SR 77, MP 158, Westbound.
- US 60, MP 228, Westbound.
- US 60, MP 291 Eastbound.
- US 89, MP 525, Southbound.

Existing data on truck escape ramp usage is sparse, and detailing the criteria for ITS implementation may necessitate a pilot project. Satellite communication is identified as a cost-feasible solution where polling rates would reflect data requests, resulting in very low air time.

The opinion of cost for this concept is $100,000 for capital costs per site to include installation, power and communications, plus $5,000 for projected operations and maintenance costs per site, per year, to include refurbishing locations and ongoing utility costs (power and satellite communications), for a total of $875,000 over five years for the seven sites.

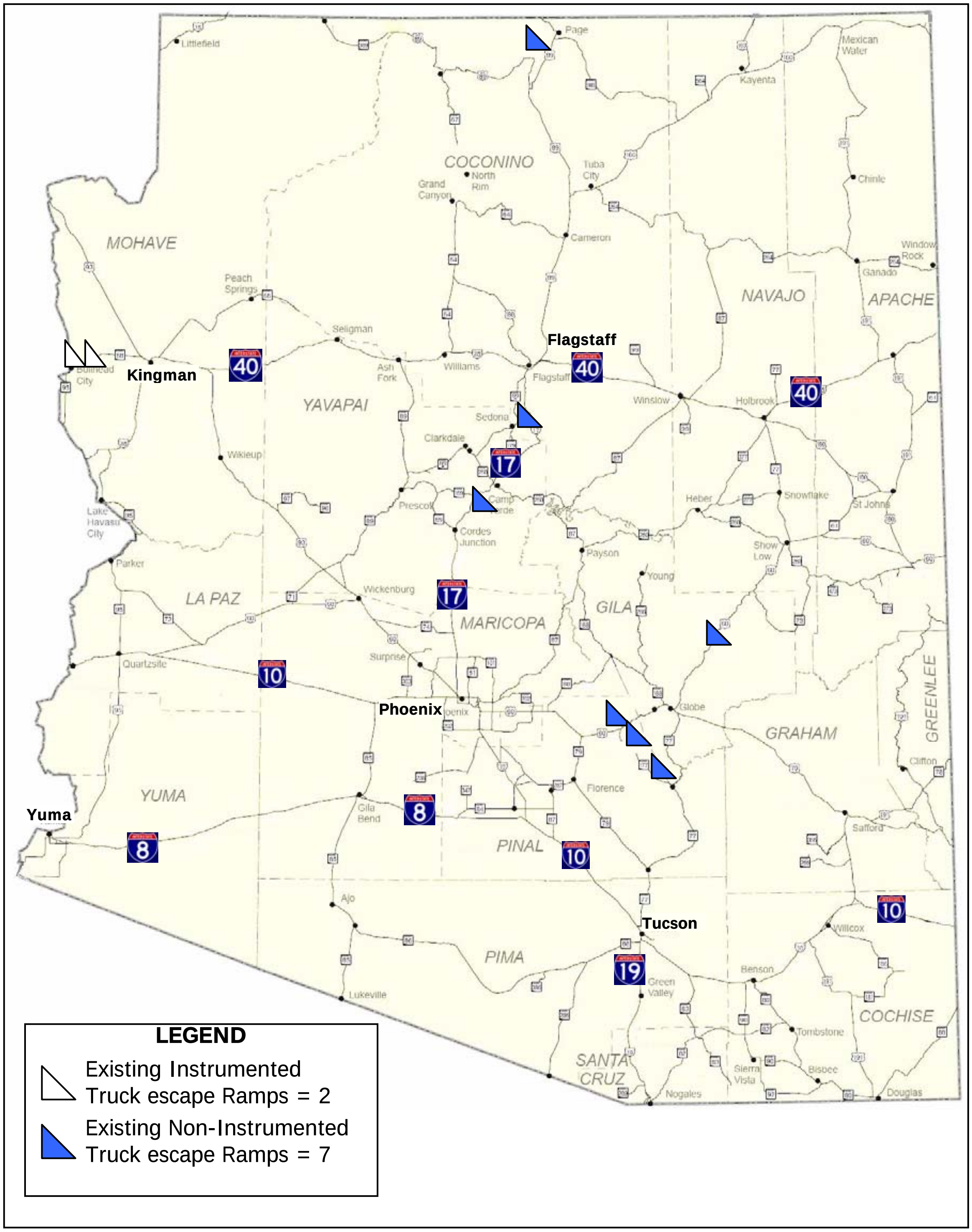


Figure 17. Truck Escape Ramp Locations

9.3 EXPANSION OF RURAL CELLULAR COVERAGE

Another potential concept to support or enhance ITS maintenance is a Request for Proposals (RFP) for rural cellular coverage, offering access to ADOT right-of-way (ROW) in rural areas, in exchange for providing additional coverage of rural state highways and interstates. ADOT would work with cellular providers by offering land to erect cellular towers for communications equipment to broaden the range of services.

Concept Benefits and Challenges

This concept would enhance internal ADOT radio communications by providing additional channels of communication for Department maintenance supervisors and technicians. Rural ITS maintenance is performed where cellular and radio service is often limited or unavailable. By providing reliable communications, much time can be saved in deploying adequate resources, and it will allow responders to provide updates and estimated times of completion. If maintenance technicians can maintain contact, their level of safety also increases for weather exposure and other road hazards.

A challenge of developing this ITS concept would be to motivate cellular providers to build out their networks. As the build-out of the system is dictated by the market (and customer needs) the cellular coverage already established is what the market currently bears. The enticement of offering in-kind services to include ROW may not be enough incentive for providers to expand their networks.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal, which was further defined in field interviews. Numerous stakeholders stated their frustration with sporadic cellular service in rural areas of the state. The Department has identified other projects that are examples of in-kind services, with ADOT providing the right-of-way to allow the erection of cellular towers with positive results.

Assuming that these contracts can be established with cellular providers, the opinion of cost for this concept is $75,000 over five years for ADOT's total costs, to include agreement preparation by either a consultant or in-house staff, site inspection time by staff, and permitting review and acceptance by either a consultant or in-house staff. With cooperation from cellular providers, this cost would entail coverage of major highways and some state routes, with an estimated increase in cell coverage ranging from the existing 25% level to possibly 50%.

9.4 ADDITIONAL DYNAMIC MESSAGE SIGN CONSTRUCTION

Dynamic Message Signs (DMS) were identified by the Districts as key tools to alerting motorists to changing roadway conditions. These signs are used for advising travelers en-route of upcoming or existing events and conditions on the roadway. The intent is to increase safety and prepare travelers for road conditions ahead, and/or to notify travelers that certain events will happen in the near future. Most ADOT locations employ standard unidirectional DMS systems, but dual units have also been deployed (see Figure 18).

The Districts identified twelve additional DMS locations, as listed below, which represent an immediate need. Except for the southbound State Route 95 site, these twelve locations are included on ADOT's TTG Statewide Infrastructure program listing of future DMS sites, and are shown in Figure 19.

- I-10, at SR 191 (Safford District).
- I-10, between I-8 and Tucson, westbound (Tucson District).
- I-17, MP 270, southbound (Prescott District).
- I-17, south of Flagstaff, northbound (Flagstaff District).
- US 60, MP 303, westbound (Globe District).
- US 70, near Duncan Port of Entry, westbound (Safford District).
- US 160 from Tuba City to Four Corners National Monument, three DMS needed eastbound (Holbrook District).
- SR 95, near Parker, northbound (Yuma District).
- SR 95, near Parker, southbound (Yuma District).
- SR 260, MP 300, near Heber, eastbound (Prescott District).

Figure 18. Existing Dual DMS in Globe

Concept Benefits and Challenges
This recommended concept addresses the specific needs identified by all of the Districts who see the benefits of alerting motorists to changing roadway conditions. The challenge for this ITS concept would be the rising costs of construction and the on-going costs for communications and power for the identified remote locations.

Concept Implementation and Cost Breakdowns
This recommended concept addresses an original project goal, which was further defined in field interviews. Through project meetings, it was identified that it is more cost effective to combine two years' worth of DMS construction contracting, in order that the mobilization and equipment costs can be reduced.

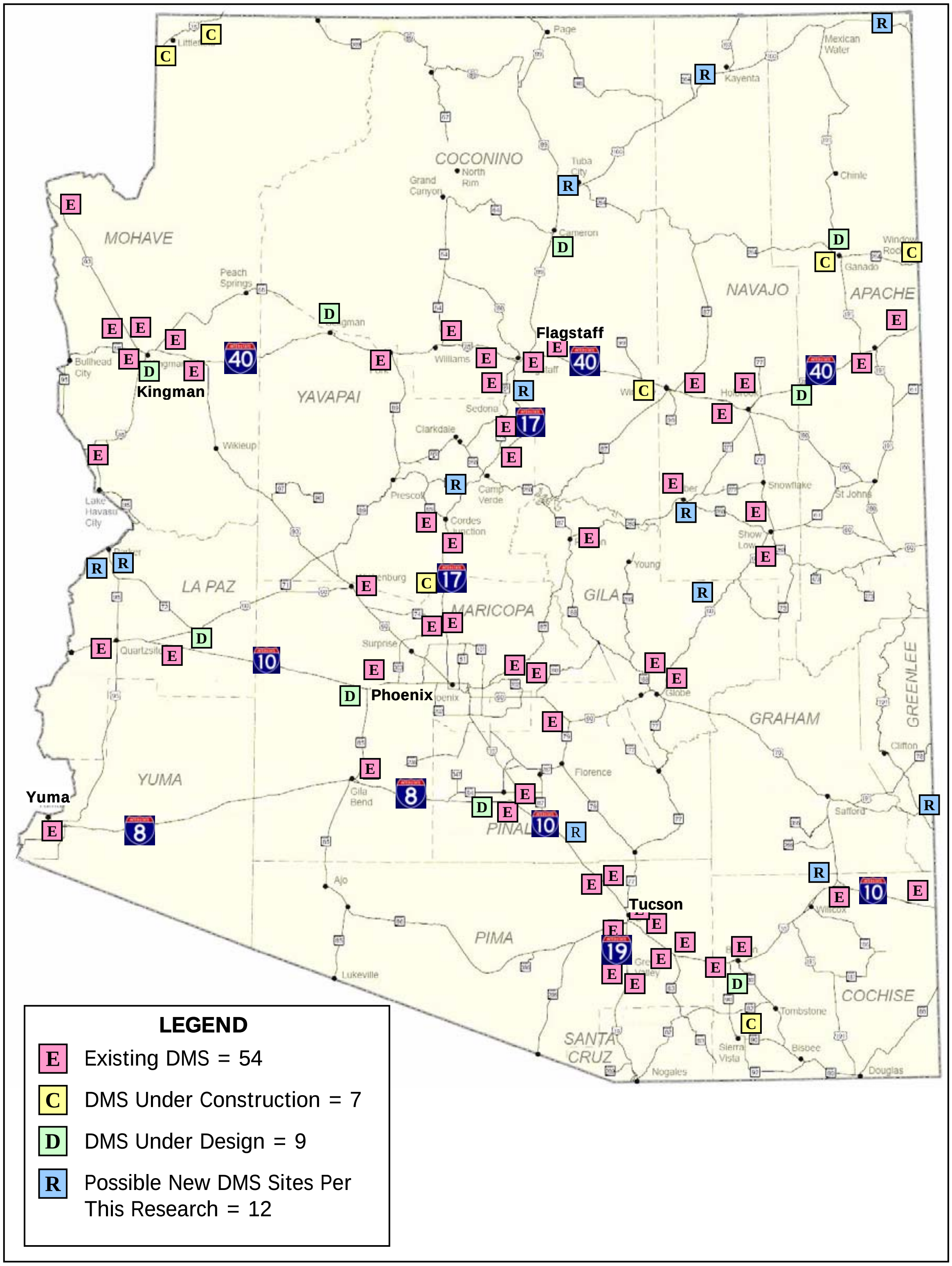


Figure 19. Existing and Future DMS Locations

Basing the costs on the current funding requirements, approximately $2.5 million would enable the construction of eight of the new DMS, over a two-year period. This would leave four signs to be designed and constructed on the next iteration of DMS deployment.

This list of locations would need to be prioritized such that eight sites are identified to be installed first. The four additional locations would need to be coupled with other planned sites to maximize efficiency and minimize costs.

A consideration should be made for establishing vendor agreements for the life-cycle of the DMS. Having such agreements in place would reduce costs associated with maintenance and provide acceptable up-time (overall operational time) for the devices.

The opinion of cost for this concept is $287,500 for capital costs per site to include installation, power and communications, plus $5,000 for projected operations and maintenance costs per site, per year, to include on-going utility costs (power and communications), for a total of $2,500,000 over five years for the first eight of the twelve additional sites, as described above.

9.5 ITS MAINTENANCE CONCEPTS SUMMARY

The proposed ITS maintenance-related concepts are presented in Table 12, including the engineer's opinion of cost for each concept.

Table 12. Engineers Opinion of Cost for ITS Maintenance Concepts

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Third-Party ITS Operations & Maintenance Contracting - $200,000 Annual O&M Contract	Scope	-	$200,000	$1,000,000
Truck Escape Ramp Monitoring - 7 Sites at $125,000 Per Site (Total)	Field	$700,000	$35,000	$875,000
Expansion of Rural Cellular Coverage - Major Highway & State Route Coverage	Scope	$75,000	-	$75,000
DMS Construction - 8 Sites at $312,500 Per Site (Total)	Scope	$2,300,000	$40,000	$2,500,000
TOTAL	-	**$3,075,000**	**$275,000**	**$4,450,000**

Note: the "Goal" column indicates whether each proposed new concept was an originally-scoped topic from the prior (2004) project, or, was developed in this study's field interview process.

10. WEATHER INFORMATION SYSTEMS:

IMPLEMENTATION PLAN

This chapter details the proposed plan that integrates numerous state-of-the-practice ITS deployment concepts for Weather Information Systems into a set of implementation recommendations to address both project goals and stakeholder needs. Each concept includes an engineer's opinion of probable cost over a five-year life cycle based on capital expenditures, on-going operations and maintenance costs, recommended staffing, ongoing utility costs and/or designated consultant fees. Recommended ITS concepts for Weather Information Systems are:

- Participation in Clarus.
- Roadway Weather Information System (RWIS) Deployment.
- Highway-Focused State Meteorologist.
- Low-Cost Weather Stations Deployment.
- Low-Visibility Detection.
- Bridge Deck Anti-Icing Monitoring.
- Intergovernmental Agreements for Flood Detection.
- Mobile Data Collection for Snowplows.

10.1 PARTICIPATION IN CLARUS

This ITS concept involves the collection of Arizona weather data for transmittal to Clarus, the future nationwide database for weather information systems. Clarus is expected to offer a significant opportunity to build an array of value-added services to disseminate high quality weather information to users. FHWA plans to conduct a multi-state demonstration of Clarus in 2007-08, with nationwide deployment planned for 2009.

For Arizona, additional statewide data inputs into Clarus would include:

- Low-Cost Weather Stations.
- County ALERT Systems.
- AWOS from Rural Airports.
- New WIS Data.

Concept Benefits and Challenges

Access to the Clarus database would be beneficial as the ultimate integration tool, providing real-time weather data that can be accessed on demand. Clarus results should be shared throughout the Districts, as the collected knowledge would be valuable for field supervisors. The benefit to the user is the availability of a compilation of quality-checked local weather observations from multiple sources. A tighter grid of weather observations will be available through Clarus than through any of the individual systems. The specific benefit of widespread deployment in Arizona would be the ability to take advantage of other states' ESS observations along the storm track. As major storms approach, the ESS data from California, Utah, Colorado, and/or New Mexico would support improved early predictions of storm severity and arrival time. A particular challenge would be assembling the state's data and delivering the data in a recognized format.

Concept Implementation and Cost Breakdowns
This recommended concept addresses an original project goal. This option would also both supplement and support the proposed statewide meteorologist (see below). The opinion of cost for this concept is $100,000 for projected annual costs to include compilation of all data statewide, management of databases and coordination/integration with the national organization, for a total of $500,000 over five years.

10.2 ROADWAY WEATHER INFORMATION SYSTEM DEPLOYMENT

This concept involves deploying RWIS at strategic locations to collect weather data. There are 17 newly-upgraded RWIS sites included in the ADOT weather-data delivery project that is currently ongoing. 48 other sites have been identified in the TTG program as potential locations for RWIS stations to be constructed, with an additional 13 locations identified through research associated with this project. Each site is shown in Figure 20.

Concept Benefits and Challenges
Expansion of the current RWIS system would assist in accurate weather forecasting and would supplement other identified ITS concepts. Additional RWIS stations would provide real-time weather data that would detail storm conditions and assist ADOT in determining measured responses. Challenges for this concept include deploying RWIS in remote locations and providing consistent maintenance checks. Arizona's previous experience in dealing with RWIS has not been positive, but a current contract for weather data services will help determine the feasibility of this concept.

Concept Implementation and Cost Breakdowns
This recommended concept addresses an original project goal, which was further defined in field interviews. The opinion of cost for each new RWIS site under this deployment plan is $16,000 for capital costs, including installing the instrumentation and establishing power and communications, plus $1,600 per site per month for projected operations and maintenance costs to include real-time data collection, hardware maintenance, and ongoing utility costs (power and satellite communications). These costs would total to $5,376,000 over 60 months (five years) for all 48 proposed new sites.

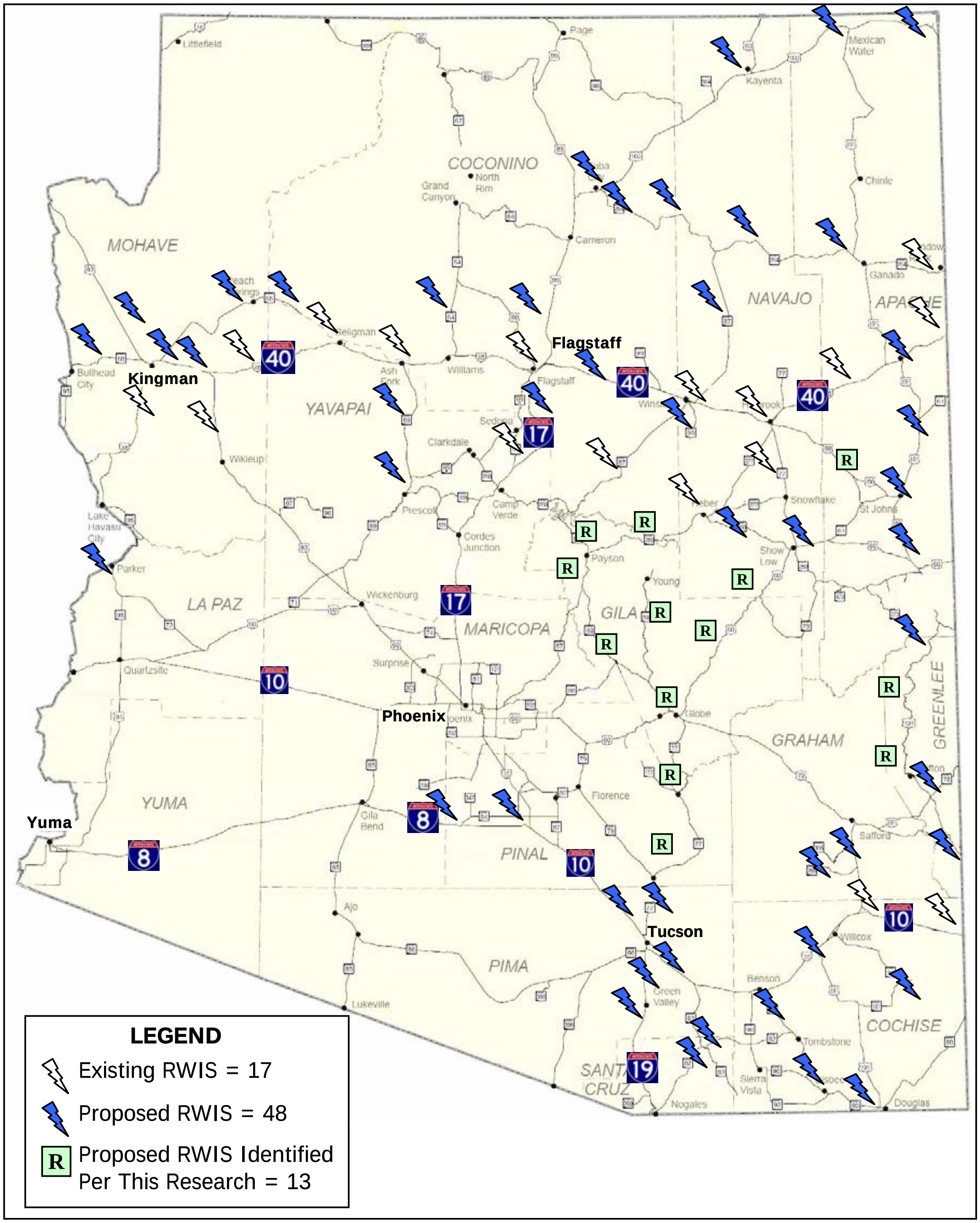


Figure 20. Roadway Weather Information Systems Deployment

10.3 HIGHWAY-FOCUSED STATE METEOROLOGIST

Another significant new weather information system concept for ADOT would be the establishment of a highway-focused State Meteorologist position for the Department. By establishing a meteorologist position, the Department would provide a single-point source for weather data collection and state-wide predictions.

This new position would establish one full-time employee, who would be dedicated primarily to forecasting highway weather conditions. This employee would coordinate closely with maintenance engineers and supervisors, particularly during the monsoon season, the fire season, and the winter season. This position would gather and analyze weather observation data and be responsible for Arizona's participation in Clarus.

Where the primary task would be weather forecasting, possible work locations for the meteorologist could be the proposed future Northern Arizona Traffic Operations Center (NATOC), the centrally-located TOC in Phoenix, or the Interim TOC in Tucson.

Concept Benefits and Challenges

The value added by implementing a forecasting team lies in assessing how each storm will affect the roads in each maintenance area. Forecast quality is enhanced through thoughtful application by a university-trained meteorologist of RWIS data, Clarus, other weather data sources, and atmospheric science principles. The information can be provided to ADOT employees with weather-related job functions such as snowplow operators and construction and maintenance managers.

A specific challenge for this concept is the year-round assignment of a single individual. The summer months are generally characterized as the statewide monsoon and wildfire season; the winter months may see severe snowstorms from October to March in the northern and eastern mountains, and rains elsewhere.

Concept Implementation and Cost Breakdowns

This concept was identified through the field interviews, and serves as a means for coordinating weather-related issues throughout the Districts.

The opinion of cost for this concept is $85,000 per year for the new staff position, for a total of $425,000 over five years. This estimate reflects part-time work during the off-seasons and overtime during winter and dust storm seasons.

10.4 LOW-COST WEATHER STATION DEPLOYMENT

In addition to the RWIS expansion, low-cost weather stations could also be deployed at ADOT district maintenance facilities. There are approximately 40 ADOT maintenance camps statewide. Weather data collected at the sites, including wind speed, wind direction, ambient temperature, barometric pressure and relative humidity, would be utilized by local forces as well as the State Meteorologist, and if also fed to the Clarus system, would further validate forecasting models and tighten the forecasting grid.

Concept Benefits and Challenges

A large deployment of low-cost weather stations would present the opportunity to standardize all of the basic weather data from each facility, which would be valuable for every supervisor. Additional equipment including static webcam shots would also benefit the District snow desk, the TOC, the ADOT meteorologist and other viewers.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal. The opinion of cost for this concept is $1,600 for capital costs per site to include instrumentation, power and communications and $180 for projected operations and maintenance costs per site per year to include the additional utility charges (power and communications) over the ADOT facility's current costs, for a total of $100,000 over five years for 40 sites.

10.5 LOW-VISIBILITY DETECTION

Low-visibility detection and warning systems are an ITS deployment plan concept that directly correlates with traveler information systems. Several locations along the major corridors statewide were identified in district interviews as having serious safety issues due to dust and fog-related low-visibility conditions. These locations are shown in Figure 21:

- I-8, MP 1 to MP 10, Yuma – dust storm issues (Yuma District).
- I-10, MP 90, Tonopah – dust storm issues (Yuma District).
- I-10, MP 170 to MP 200, Firebird Lake to Casa Grande – dust storm issues (Tucson District).
- I-10, MP 365 to MP 380, Bowie to San Simon – dust storm issues (Safford District).
- I-17, MP 317, Woods Canyon – fog issues (Flagstaff District).

The proposed system would detect low-visibility conditions, relay that information to local maintenance supervisors, and activate warning systems for the traveling public.

If fully integrated with a warning system, this system can alert freeway operators to low visibility conditions. Low visibility monitoring systems can be placed along the problem corridors with adequate spacing to yield the most effective returns.

Concept Benefits and Challenges

A direct benefit for deploying a low-visibility detection system is alerting motorists to changing conditions with an automated warning message, so that they can then adjust their driving habits accordingly.

Specific challenges to deployment include hardware failures due to harsh weather conditions, installation of lightning protection systems, communication disruptions due to misaligned antennas, and regional communications issues with data transmission.

Concept Implementations and Cost Breakdowns

This concept was identified through field interviews. The opinion of cost for this concept is $60,000 for capital costs per site to include system installation, instrumentation, power and communications, plus $3,000 for projected operations and maintenance costs per site, per year. This figure includes on-going utility costs as well as system calibration and system integration, resulting in a total cost of $1,125,000 over five years for 15 visibility monitoring sites.

The initial costs for deployment represent the anticipated difficulties of establishing the necessary utility services in the more remote areas of Arizona.

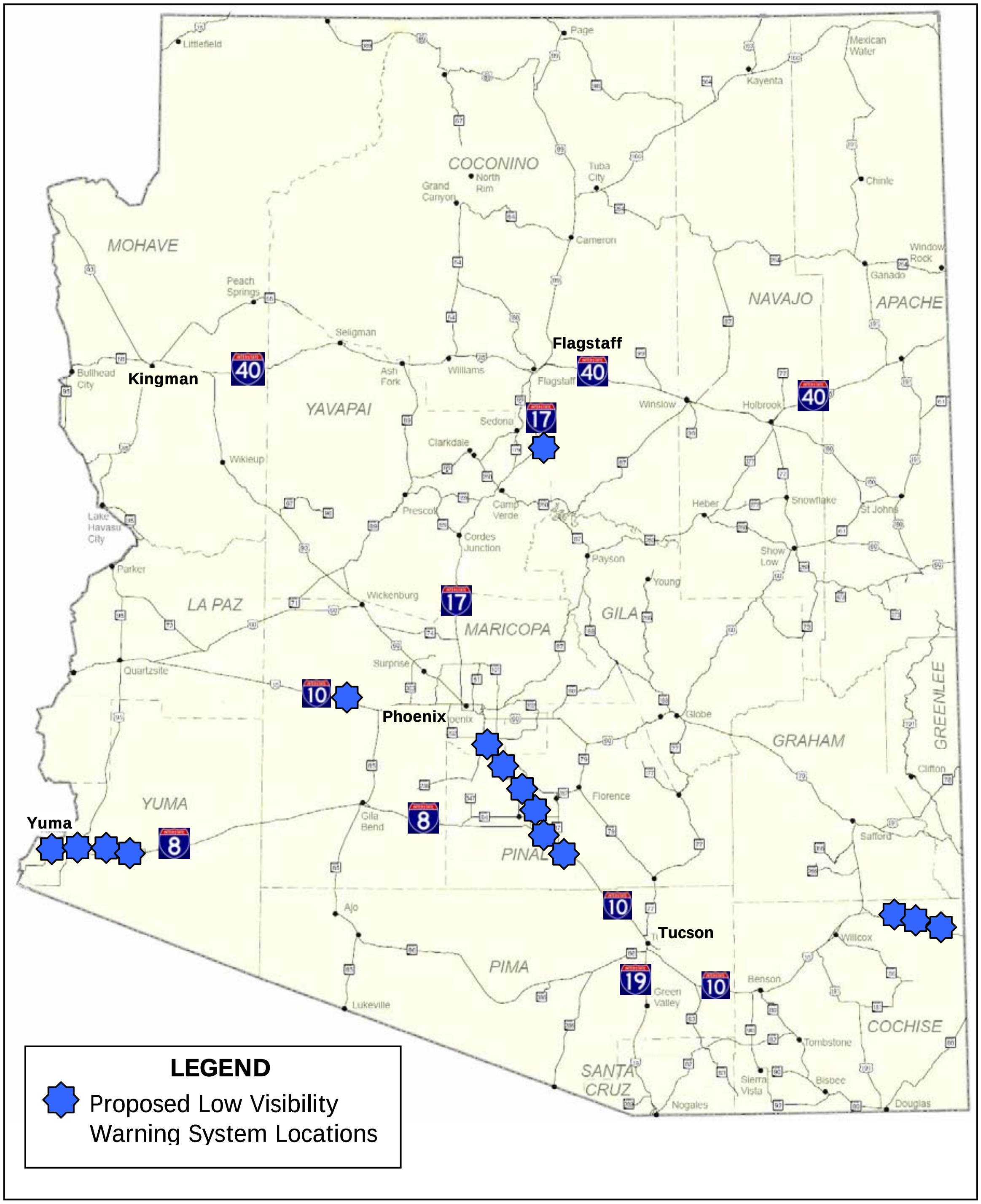
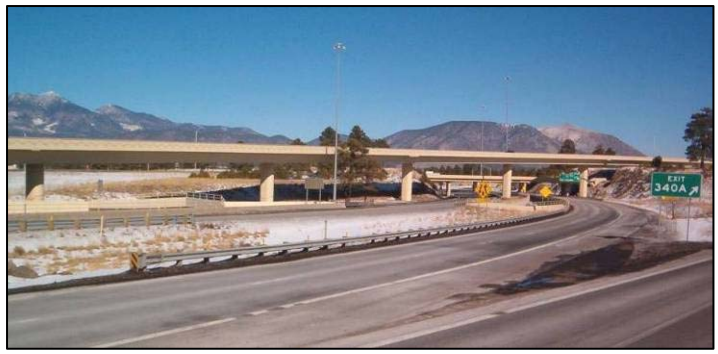


Figure 21. Low Visibility Monitoring Locations

10.6 BRIDGE DECK ANTI-ICING MONITORING

Another weather-related ITS deployment concept is integrated bridge deck monitoring and anti-icing systems. This system includes automated, proactive sensors to detect bridge deck surface conditions. The anti-icing components include a material tank, conduit, and sprayers. Monitoring software records the system operation history, which includes materials levels, activation time, and activation duration. These system details and materials data are delivered to maintenance facilities in real time to be evaluated for usage levels, efficiency and accuracy.

An alternative to this concept would involve a reactive communications link to District supervisors, where activation of the anti-icing systems would automatically initiate contact with a predefined email address or a pager number. The system would send a detailed message to a designated contact upon activation.



Establishing communications for this alternative would be the major challenge, as it is dependent upon communications availability. For some sites, it would be expensive to provide the communications and power infrastructure.

Concept Benefits and Challenges
Benefits for deploying anti-icing systems include automated preemptive responses to potential icy conditions, and alerting motorists to hazardous conditions with an automated response. Specific challenges to deployment include hardware review and data analysis to ensure that the hardware is accurately calibrated.

Concept Implementation and Cost Breakdowns
There are several locations where test pilot projects for bridge anti-icing stations are recommended for deployment. A preliminary phase for installing bridge anti-icing systems would be to establish implementation criteria such that bridges can be prioritized for system installation. Each system would be reserved for the highest priority bridge. These locations are:

- I-40, MP 74, Peacock Wash Bridge EB – Willows Area (Kingman District).
- I-40, MP 74, Peacock Wash Bridge WB – Willows Area (Kingman District).
- I-40, WB to I-17 SB Flyover Ramp (Flagstaff District).

This was a concept identified through field interviews. The opinion of cost for this concept is $80,000 for capital costs at each site, to include installation of tanks, conduit and sprayer equipment, power, and communications. The annual operations and maintenance costs would be $4,000 per site to include maintenance of chemical levels, regular site evaluations, and on-going utility costs for power. The total concept cost would be $300,000 over five years, for three sites.

10.7 INTERGOVERNMENTAL AGREEMENTS FOR FLOOD DETECTION

Several highways across the state were identified as flood-prone corridors, including US 95 and SR 97. Through the stakeholder interview process, numerous locations for flood detection were identified that already have monitoring systems in place, under control by other agencies.

This ITS concept is to establish intergovernmental agreements to share flood detection data between the partner agencies. This would enable partner agencies to be promptly alerted of flooding conditions, allowing for a coordinated response, or individual responses to address roadway safety concerns. Sensors can be placed at strategic locations at the discretion of the local Districts, to maximize the benefit to ADOT operations managers.

The Kingman District created an IGA with Mohave County in 2006, as discussed in Chapter 5. The initial cost of a base station and one site was $12,000. Additional sensor sites, as determined by ADOT, cost from $3,500 to $7,000 each. Three more sensor sites have been added for $13,000, and the total ADOT cost commitment of this IGA is $69,000 for the base station system and up to 9 ADOT-located sensors.

The other ADOT Districts can also utilize date from flood-sensor sites by establishing ALERT system IGAs with their partner counties, and with state agencies such as the Arizona Department of Water Resources. There are 11 other counties with these systems, a total of more than 500 sensor sites (see Table 7).

Concept Benefits and Challenges

IGAs with local agencies can be a cost-effective method of getting high water warnings.

Concept Implementation and Cost Breakdowns

This concept was identified through field interviews. If these IGAs were established with the other 11 county flood control agencies, at approximately $70k per agency including the procurement of the computer system and 8 to10 sensors, then the opinion of cost for this concept would be $770,000. As with the existing Mohave County IGA, a system could be installed in increments to spread the cost over five years.

10.8 MOBILE DATA COLLECTION FOR SNOWPLOWS

The major ADOT application for mobile data acquisition systems would be to outfit the state's snowplows with AVL for data collection and vehicle operations reporting.

There are nearly 250 ADOT snowplows throughout the state; 177 AVL-candidate plows were identified in discussions with six key rural districts: Kingman, Flagstaff, Holbrook, Globe, Prescott, and Safford. These districts experience the majority of severe winter weather in the state, and may benefit the most from deployment of this concept.

Concept Benefits and Challenges

The benefits of real-time Mobile Data Collection Systems include:

- Collecting data while performing other tasks and duties saves the operator's time.
- No extra vehicles are needed, as all data collecting equipment can be added to the vehicles performing other duties.
- Mobile data collection can be performed in different areas of the district depending on needs and requirements, whereas static data collection systems can only monitor a single specific location.
- Response can be in real-time, when data collected by operating snowplows can be processed and used for ongoing maintenance decisions.
- Mobile data collection can be performed by a wide variety of vehicles, including: maintenance trucks (snowplows, graders), highway patrol units, construction and inspection vehicles, pilot cars, tow trucks, and emergency vehicles.
- Long term substantial financial benefits may be a result of high efficiency of single vehicle operations, leading to fleet reduction.
- Detection and monitoring of chemical formula, the amount applied, and the available supply status of the roadway treatment.
- Material monitoring by the operator and by the dispatcher, without additional manual driver efforts.
- Reduced driver input effort in the chemical deployment operations.
- Integration of mobile data collection systems on other maintenance vehicles and cost sharing between AVL technology, fleet dispatch and data collection systems.

AVL technology would also aid in snowplow operations where roadway treatment information could be relayed to the field supervisors, identifying which routes and, specifically, which lanes have been plowed and/or treated. This data would support operational decisions to maintain desired conditions on priority routes in dynamic weather conditions. Supervisors would have a detailed and comprehensive understanding of the conditions in their areas during major winter storms, and have the best available information to adjust snowplow operations accordingly.

Some of the anticipated challenges with Mobile Data Collection Systems would be:

- Establishing real-time communications in remote areas.
- High initial costs to implement the system; however, integration of MDSS with GPS-enabled AVL technology can help to reduce capital costs.
- Data processing requires sorting to eliminate needless data, while preserving relevant, useful data.
- Consistent data between the various sources, and incorporating the data into one format to facilitate data conversion.
- Mobile data collection sensors are more susceptible to damage or wear-and-tear than permanent data collection stations.

Satellite communications were identified as one promising solution for remote areas, but it is recognized as a significant dollar investment for deployment due to the ongoing monthly fees for this service. The minimum monthly fee for satellite communications service is around $100, but it may only be necessary during the winter weather season.

Real-time communications would be necessary to relay desired information to supervisors, such as roadway temperatures, visibility conditions, ambient temperatures, barometric pressure, etc. This information, furnished in near-real time, would aid the decision-makers with deployment strategies to effectively deal with storm conditions.

Concept Implementation and Cost Breakdowns

This recommended concept addresses needs identified through field interviews. Because of ADOT's previous experience with AVL deployment challenges, it is recommended that these systems be deployed in the Globe and Kingman Districts on a pilot project basis. The best identified test cases would be in areas with poor cellular coverage to test reliability and operations on a small scale.

Involving both districts in a pilot deployment would yield better results for statewide deployment given the diverse topography of the Globe and Kingman Districts, which creates a significant communications challenge. A test deployment demonstrating data quality and detail would also resolve liability issues regarding the timing and location of all plowing activities performed by the snowplows with AVL systems.

The number of snowplows per snow district is shown in Table 13. The Globe District has 34 first-line snowplow trucks, and Kingman has 20 snowplows. All of them could be

outfitted with the mobile data collection devices and satellite communications, for a total of 54 vehicles in a future pilot project.
The opinion of cost for this concept is $10,000 for capital costs per vehicle, to include instrumentation and integration, plus $400 annual projected operations and maintenance costs per vehicle system, to cover the maintenance of databases and data review, for a total of $648,000 over five years for 54 snowplow trucks.

Table 13. Identified Snowplows per District

District	Number of Snowplows
Kingman	20
Flagstaff	43
Holbrook	42
Globe	34
Prescott	20
Safford	18
TOTAL	**177**

An alternative deployment strategy would be to eliminate the real-time communications aspect of the test project, and establish downloading protocols after snowplows have returned from operations. Information detailing deployed materials, route efficiency, and up-time to reduce overtime hours could all be determined after the fact, providing an opportunity to debrief operators after a major weather event.

The tradeoff for this type of delayed (near-real time) communication is that not having these details during the storm has a significant operational impact. Modifications to the deployment of materials and assignments of individual snowplows could not be implemented during the storm event on the basis of this resource.

This approach would be a practical alternative where satellite communications are ineffective and/or too costly to implement. For this alternative, the opinion of cost is $8,500 for capital costs per vehicle and $300 for operations and maintenance costs per vehicle per year, for a total of $540,000 over five years for 54 vehicles.

10.9 WEATHER INFORMATION SYSTEMS CONCEPTS SUMMARY

The proposed weather information ITS concepts are presented in Table 14, including the engineer's opinion of cost for each concept.

Table 14. Engineers Opinion of Cost for WIS Concepts

Deployment Concept	Project Goal	Initial /Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Participation in Clarus - Database Development & Maintenance, Coordination with National Agency	Scope	-	$100,000	$500,000
RWIS Deployment - 48 Sites at $112,000 Per Site (Total)	Scope	$768,000	$921,600	$5,376,000
Highway-Focused State Meteorologist - 1 Position at $85,000 Annual Salary	Field	-	$85,000	$425,000
Low Cost Weather Station Deployment - 40 Sites at $2,500 Per Site (Total)	Scope	$64,000	$7,200	$100,000
Low Visibility Detection - 15 Sites at $75,000 Per Site (Total)	Field	$900,000	$45,000	$1,125,000
Bridge Deck Anti-Icing Monitoring - 3 Locations at $100,000 Per Site (Total)	Field	$240,000	$12,000	$300,000
IGAs for Flood Detection - 11 County Agencies at $70,000 Per IGA	Field	$770,000	-	$770,000
Mobile Data Collection for Snowplows - 54 Snowplows at $12,000 Per Vehicle (Total), *using satellite communications.	Field	$540,000	$21,600	$648,000
TOTAL	-	**$3,282,000**	**$1,192,400**	**$9,244,000**

11. TRAVELER INFORMATION SYSTEMS:

IMPLEMENTATION PLAN

The project-defined focus area relating to traveler information systems was Highway Advisory Radio (HAR). Throughout the course of the project, several additional areas of interest developed as regards the effective delivery of timely information to motorists. This chapter addresses the general focus area of traveler information systems; it proposes a plan to integrate numerous state-of-the-practice ITS deployment concepts into a set of project recommendations to address both project goals, and stakeholder needs.

Each concept includes an engineer's opinion of probable cost over a five-year life cycle based on capital expenditures, on-going operations and maintenance costs, recommended staffing, ongoing utility costs and/or designated consultant fees. Under traveler information systems, the following ITS concepts are identified for implementation:

- District-Owned Portable Highway Advisory Radio.
- Work Zone HAR Standard Specifications.
- Statewide Permanent HAR Sites.
- Intelligent Rest Areas.
- Corridor Travel Time Measurements.
- Emergency Detour Routing.

11.1 DISTRICT-OWNED PORTABLE HIGHWAY ADVISORY RADIO

This concept calls for purchasing one portable highway advisory radio (HAR) system for each of the rural districts, for deployment for long-duration incidents. This is the most common type of traveler information station operated by a DOT.

Concept Benefits and Challenges

Portable HAR units provide a benefit for the deploying agency, where deployment can alert travelers in the area to incidents of a long-term duration. A challenge for the Districts is maintaining the existing equipment, and the leasing option might allow a more focused deployment with complete service. Portable units are vulnerable to damage from passing vehicles and vandalism.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal, which was further defined in field interviews. Portable HAR units cost approximately $25,000 to $30,000 each, and one system should be purchased for each rural district. Another alternative offers cost savings on the initial purchases, as portable HAR units can be leased for $1,500 per month with complete service. Leasing for 20 months, on average, over five years will cost $30,000 each for the proposed eight portable HAR units statewide. This 20-month period is the break-even point, roughly equal to the cost of purchasing the units outright.

With appropriate training and dedicated staff for message management, the Department can maintain the systems and purchase the units outright. The opinion of cost for this concept is $25,000 for capital costs per unit and $1,000 for projected operations and maintenance costs per unit per year to include message maintenance, deployment and communications, for a total of $240,000 over five years for eight units.

11.2 STANDARD SPECIFICATIONS FOR WORK ZONE H.A.R.

The concept for establishing work zone Highway Advisory Radio would involve developing a standard specification that would be performance-based, include update of messages, identify duration of service, and require vendor-provided communications. This specification would be included in major construction projects that would require HAR for roadway operations during any construction phase.

Concept Benefits and Challenges

Work zone deployments of portable HAR and appropriate messages would be consistent throughout the state and contain universal operating procedures.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal. After development, this specification would establish the criteria for inclusion of HAR in bid documents for construction projects. The opinion of cost to develop this concept is $5,000 which would include consulting fees to produce the specifications.

11.3 PERMANENT HIGHWAY ADVISORY RADIO SITES

Another recommended ITS concept for traveler information systems is the deployment of permanent HAR stations statewide. These units are similar to the portable HARs, but the fixed locations would be strategically located near significant ports of entry to the state. The districts may also deploy these units for other permanent locations of interest or near key decision points on rural corridors.

Concept Benefits and Challenges

The benefits are similar to portable deployment, where motorists can be updated on changing roadway conditions. Deployment costs are cheaper for permanent locations and enclosed or manned sites can provide security. A challenge for this concept is that strategic locations might be constrained by power and communications limitations.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal, which was further defined in field interviews. Locations for proposed deployment included ports of entry, and sites along the I-40 corridor to alert motorists of highway and weather condition ahead. These locations are identified in Figure 22. The opinion of cost for this concept is $20,000 for capital costs per site to include installation with power and communications, and $1,000 for projected operations and maintenance costs per site per year to include ongoing power and communications costs, for a total of $500,000 over five years for 20 sites.

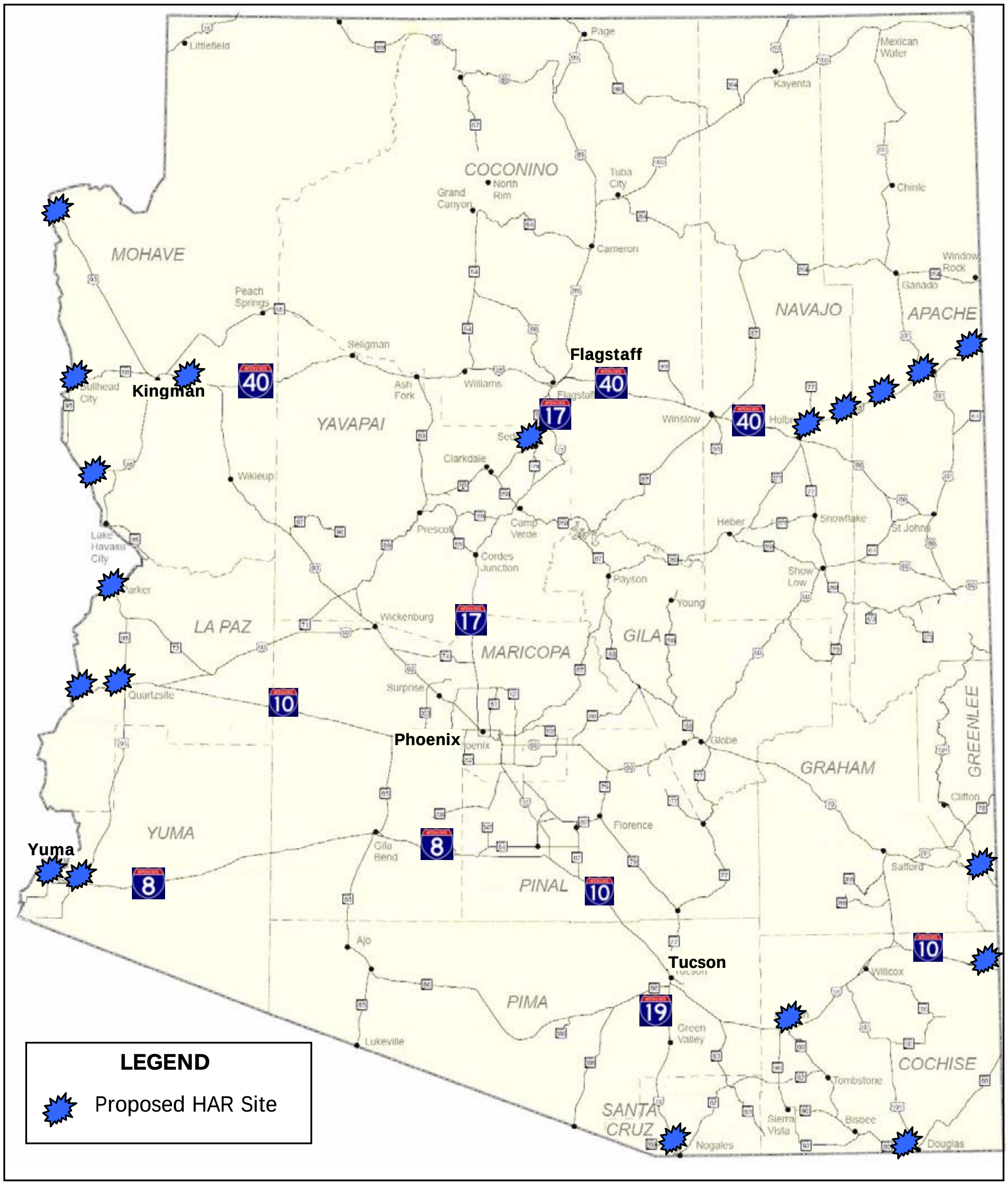


Figure 22. Permanent HAR Deployment Plan

11.4 INTELLIGENT REST AREA DEPLOYMENT

This concept involves deploying specific ITS devices at existing statewide rest areas for traveler information and wireless access points. This concept includes providing the following components at rest areas and points of interest:

- Wi-fi 511 Access Points.
- Interactive Traveler Information Stations.
- Low-Cost Weather Sensors.
- Traffic Monitoring Cameras.
- Security Cameras.
- Communications Links.
- Potential Enhancements for Cellular Service.
- HAR for Expected Travel Times and Weather Conditions.

All monitored data would be communicated back to a centralized point for collection and information dissemination purposes.

Concept Benefits and Challenges

One of the primary concerns identified in the research for this project is the lack of advance notice for travelers moving through the state. Adverse weather conditions catch motorists off guard who cannot deal with the roadway conditions. These ITS-enhanced rest areas can both inform long-distance travelers of regional conditions, and also entice them to take a break from their trip and reduce driver fatigue. While rest area utilities generally are in place, a challenge for this concept is still to secure the facilities and provide continuous reliable service for the customers.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal, which was further defined in field interviews. There are 15 existing Interstate rest area sites statewide. The proposed locations are identified in Figure 23.

The opinion of cost for this concept is $43,000 for capital costs per site to include installation, instrumentation, integration and communications, and $1,000 for projected operations and maintenance costs per site per year to include maintaining services and additional utility costs (power and satellite communications), for a total of $720,000 over five years for 15 existing Interstate rest area complexes.

These costs are an overall average per site, for eleven dual rest area locations (both sides of the highway), and four single rest area locations. The sites with shared bi-directional rest areas are Painted Cliffs, Sunrise/Sunset Point, Burnt Well, and Canoa Ranch.

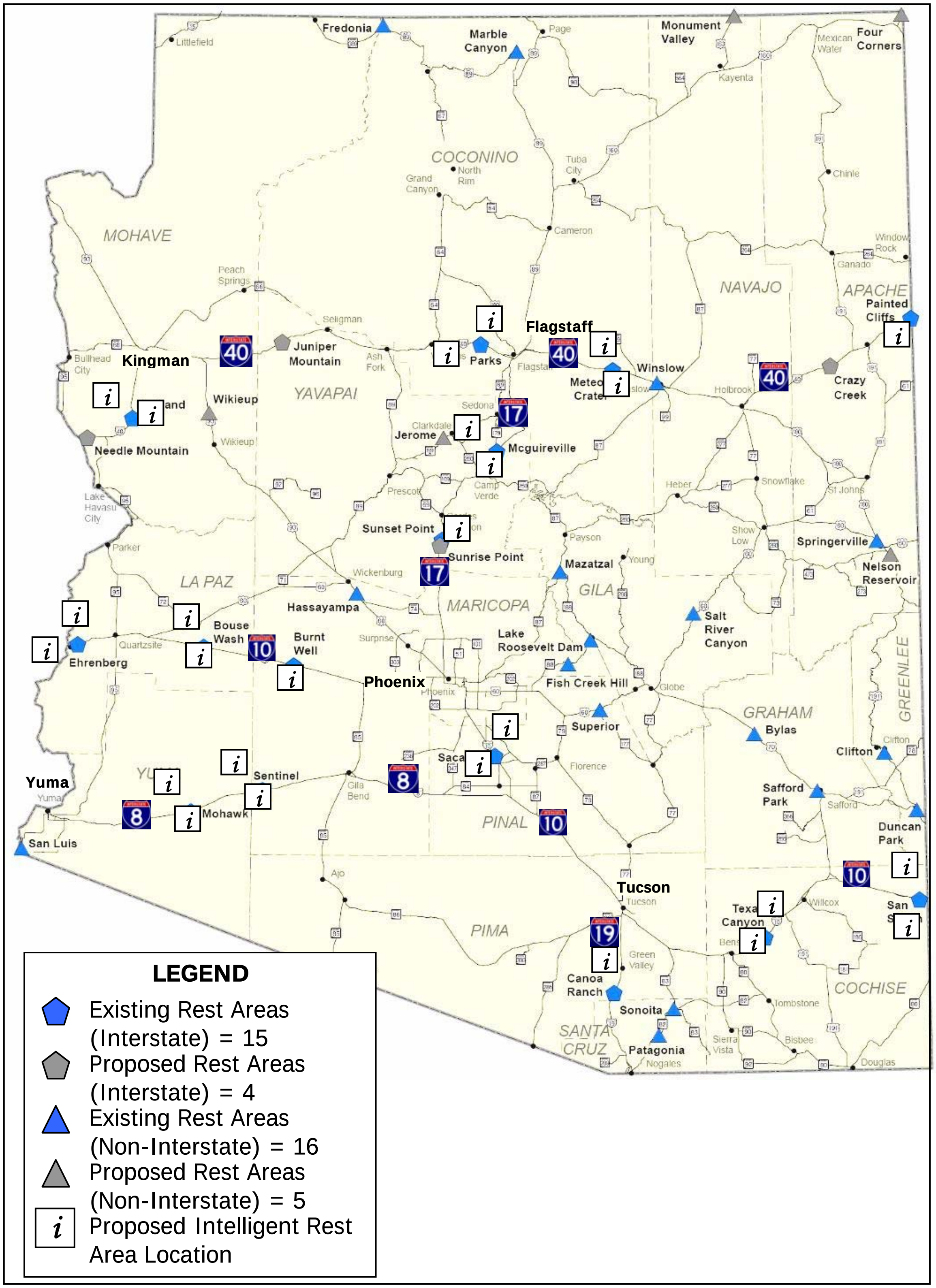


Figure 23. Intelligent Rest Area Implementation

11.5 CORRIDOR TRAVEL TIME MONITORING

Another potential ITS concept for enhanced traveler information is corridor travel time reporting systems. The primary technology for this concept would be license plate reader (LPR) systems at key points along the major highway corridors to capture license plate images. Optical character recognition software can interpret the license images into text, to be stored into a database.

The data is date- and time-stamped, allowing for a comparison between two separate license plate readers placed at a known distance apart from each other. Once the two separate databases are cross-referenced to each other, the individual vehicle's speed can be computed. A series of computations for numerous vehicles can provide the average speed over a designated stretch of roadway, to determine the current expected travel time.

Concept Benefits and Challenges

The key benefit of LPR systems is to provide travelers with quasi-real-time computations for trip time prediction. With the anticipated speeds already known, drivers can make a quick comparison to determine if their original trip duration is accurate. Travel times are highly rated by the public, but a major challenge is the perceived privacy intrusion, if governmental agencies are reviewing license plates and accumulating data.

Concept Implementation and Cost Breakdowns

This concept was identified through the district field interviews. The critical corridors identified for travel time monitoring are:

- I-17 from I-40 to Loop 101.
- I-10 from Loop 202 to Ina Road.
- SR 85 from I-10 to I-8.
- I-8 from SR 85 to I-10.

These locations are identified in Figure 24. The travel time measurements for I-17 will provide information for the trip from Flagstaff to Phoenix, while measurements for I-10 will predict travel times from Phoenix to Tucson. The travel time figures for the I-8 and SR 85 routing will be key comparative information for those considering bypassing the Phoenix metropolitan area. The system server would feed corridor speeds and travel time details to the AZ 511 traveler-information resource, and potentially to key DMS sites.

The opinion of cost for this concept is $100,000 for capital costs per site to include bi-directional installation with power and communications, and $2,500 for projected operations and maintenance costs per site per year to include data collection, system maintenance, sensor calibration, data analysis and distribution of results, and on-going utility costs (power and satellite communications), for a total of $900,000 over five years for eight two-way monitoring sites.

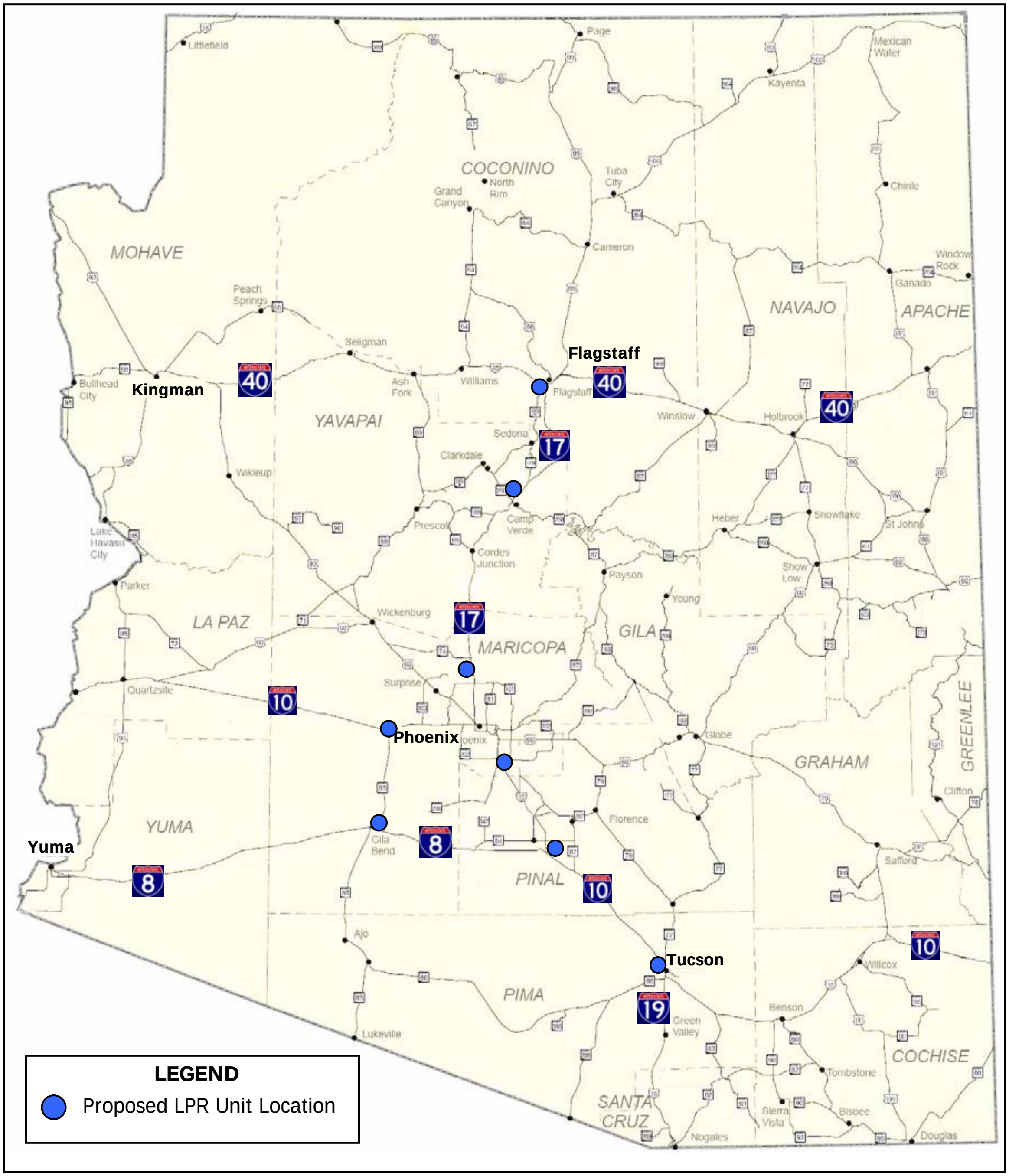


Figure 24. Travel Time Monitoring Stations

11.6 EMERGENCY DETOUR ROUTING

This recommended concept identifies proposed emergency detour routes to provide predetermined guidance for motorists diverted due to roadway closures on major rural corridors. Signage options could include extinguishable message signs, flashing beacons, temporary traffic signals, or static signs.

A combination of guide signage types would be recommended, where extinguishable message signs are used on the major corridor, and permanent static signs are placed to identify the predetermined detour route for diverted motorists.

Concept Benefits and Challenges

A primary benefit for this concept is the timely remote activation of emergency route signs, representing a great time savings for both maintenance personnel and motorists.

A challenge for this concept would be to provide realistic travel times and time savings to the motorists if they use the emergency detour routes. Otherwise, travelers may choose to wait out the duration of the provoking incident. Other challenges include power- and communications-restricted rural locations.

Concept Implementation and Cost Breakdowns

This concept was identified through the field interviews with the districts. The project stakeholders identified a number of key alternate routes throughout the state, as illustrated in Figure 25.

This concept proposes 33 extinguishable message signs. The opinion of cost for this concept is $4,500 for capital costs per site to include installation, integration, power and communications, plus $300 for projected operations and maintenance costs per site per year, to include site utility services. The total cost to deploy this concept as described would be $198,000 over five years for 33 sites.

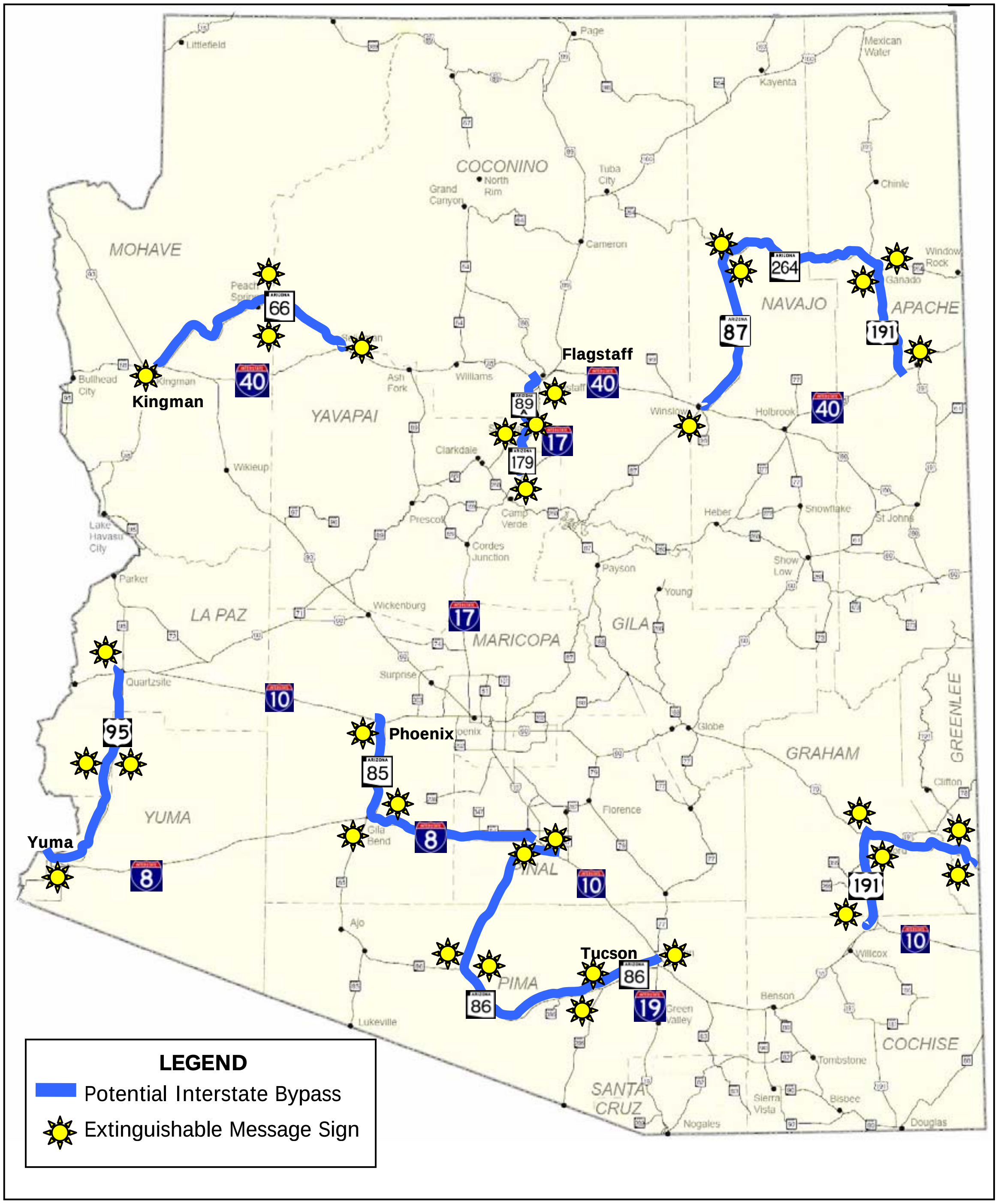


Figure 25. Emergency Detour Routes

11.7 TRAVELER INFORMATION SYSTEMS CONCEPTS SUMMARY

The proposed ITS concepts for this focus area are presented in Table 15, including the engineer's opinion of cost for each concept.

Table 15. Engineers Opinion of Cost for Traveler Information Systems Concepts

Deployment Concept	**Project Goal**	**Initial / Capital Costs**	***Annual* Operating & Maintenance Costs**	**Opinion of Cost (*Over 5 Years*)**
Portable HAR – 8 Units at $30,000 Each (Total)	Scope	$200,000	$8,000	$240,000
Work Zone HAR Standard Specifications - One-Time Consultant Fee	Scope	$5,000	-	$5,000
Permanent HAR Sites - 20 Sites at $25,000 Per Site (Total)	Scope	$400,000	$20,000	$500,000
Intelligent Rest Area Deployment - 15 Sites at $48,000 Per Site (Total)	Scope	$645,000	$15,000	$720,000
Corridor Travel Time Monitoring - 8 Sites at $112,500 Per Site (Total)	Field	$800,000	$20,000	$900,000
Emergency Detour Routing - 33 EMS at $6,000 Per Sign (Total)	Field	$148,500	$9,900	$198,000
TOTAL	-	**$2,198,500**	**$72,900**	**$2,563,000**

12. MOTORIST ASSISTANCE AND SAFETY SERVICES:

IMPLEMENTATION PLAN

This chapter has evolved from the original project focus area of Motorist Assist Patrols (MAP) into a wider range of both motorist assistance and safety services, in support of all types of ADOT rural operations. It details a proposed plan that integrates numerous state-of-the-practice ITS deployment concepts into a set of project recommendations that will address both the project goals, and expressed stakeholder needs.

Each concept includes an engineer's opinion of probable cost over a five-year life cycle based on capital expenditures, on-going operations and maintenance costs, recommended staffing, ongoing utility costs and/or designated consultant fees. Several ITS concepts are presented here that address motorist assistance and safety issues:

- Standard MAP Specification.
- Collision Reduction and Safety Help Vehicles.
- Enhanced Radio Communications with DPS.
- District Training Programs.

12.1 STANDARD SPECIFICATION FOR M.A.P.

This concept involves developing a standard ADOT specification for Motorist Assist Patrols for long-duration construction projects. Several ADOT projects have effectively utilized a MAP program that was required in project specifications. This specification could also be expanded to include emergency tow services or other additional features.

Concept Benefits and Challenges
A boiler-plate specification would provide a sound, consistent basis for a basic motorist assistance program to ensure the safety of both the public and the responder.

Concept Implementation and Cost Breakdowns
This recommended concept addresses an original project goal. The opinion of cost to establish motorist assist program specifications for construction projects is $30,000, which would include consulting fees to produce the specifications.

12.2 COLLISION REDUCTION AND SAFETY HELP VEHICLES

This concept involves procuring Collision Reduction and Safety Help (CRASH) vehicles for highway incident response by the Districts. Kingman, Phoenix, Tucson, and Yuma districts have been successful in procuring new specialty vehicles that often are equipped with four-wheel drive, and all units have message boards, emergency lights, all-purpose utility beds, extended cabs, and additional responder equipment.

The recommended 20 additional vehicles statewide would be assigned at each district's discretion to key maintenance yards where they would be of greatest benefit, and where incident-trained manpower is available.

Concept Benefits and Challenges
A benefit for this concept would be that districts could deploy these specialty vehicles that have been modified and equipped to specifications at their discretion for safer, more efficient incident management. In particular, back-of-queue protection could be provided for incidents, to reduce the likelihood of secondary collisions.

Concept Implementation and Cost Breakdowns
This recommended concept addresses an original project goal. The opinion of cost for this concept is approximately $1,500 per unit, per month, or $18,000 per year, based upon standard ADOT fleet rental and usage charges and fuel costs. The Equipment Services internal rental charges to the districts apply to all fleet vehicles and portable devices. The total cost to deploy the proposed 20 vehicles over five years is $1,800,000.

12.3 ENHANCED INTERNAL AND D.P.S. RADIO COMMUNICATIONS

This recommended concept will enable direct contacts between dissimilar ADOT radio systems. It will also permit direct car-to-car voice communications between rural DPS patrol officers and ADOT maintenance workers. The DPS patrol units operate with UHF mobile radios, while ADOT radios are VHF-band units. For direct communications between ADOT and DPS, the low-cost, near-term solution is to equip every Highway Patrol vehicle with a second ADOT-compatible VHF radio.

Concept Benefits and Challenges
This concept would benefit traffic control response, technician assistance for incident response, and overall responder safety. DPS and ADOT can coordinate their field-level efforts, allowing ADOT to conduct traffic control while DPS can concentrate on the incident scene and investigation. Communications can be a challenge for this concept in initial stages of implementation, but with training, coordination benefits can be realized.

A related challenging field situation is the use of 800 MHz UHF radios by ADOT in the Phoenix region only. Districts surrounding Phoenix need a second radio to communicate directly for coordination of incident response, as well as for normal maintenance activity.

Concept Implementation and Cost Breakdowns
The DPS radio issue was a concept identified as an original project goal, and an ADOT-DPS pilot project in 2006 convincingly validated this solution. Approximately 440 DPS vehicles are currently without a supplemental ADOT VHF radio. The opinion of cost for

procuring VHF radios for rural DPS vehicles is based on the purchase of 440 radios at $1,500 per unit including installation, for a total of $660,000.

Since all hardware would be installed in DPS vehicles, it is understood by management of both departments that DPS alone must fully fund this recommended concept. These costs are not reflected in the project summary tables.

In addition to the VHF radios for DPS vehicles, this ITS concept also provides for internal radio interoperability enhancements. Installation of secondary 800 MHz radios in the ADOT Maintenance Supervisors' vehicles in the Prescott, Tucson, Globe and Yuma Districts would allow direct contact as needed with the Phoenix District personnel, on their primary frequency.

This recommendation addresses an original project goal; the concept also includes field training, and regional coordination meetings. It addresses agency issues of incident response coordination at the Phoenix region's urban fringe. 50 Phoenix-mode 800 MHz radios would be installed by the four perimeter districts in their supervisors' vehicles, at $1,500 each, for an implementation total of $75,000.

12.4 DISTRICT TRAINING PROGRAMS

Training programs are recommended to be initiated for several topics including Arizona's Quick Clearance Law (Arizona Revised Statute 28-674), radio operations protocols for interagency communications, and joint incident response and debriefing.

Concept Benefits and Challenges

The benefit for this concept would be to inform rural districts of modifications to procedures and protocols, as well as refresher courses to review existing conditions, protocols, and techniques that would help keep operations current. This would also offer a method for providing refresher training for existing programs.

Concept Implementation

This was a concept identified through field interviews. This training concept would involve developing presentation materials and establishing seminars in the rural Districts. This could be developed and administered with the assistance of a third party contractor.

The opinion of cost for a district training program for the Quick Clearance law, radio operations protocols, and joint incident response training is $8,000 per year for a total of $40,000 over five years.

12.5 MOTORIST ASSISTANCE AND SAFETY CONCEPTS SUMMARY

The proposed ITS concepts for this focus area are summarized in Table 16 (p.144), including the engineer's opinion of cost for each concept.

Table 16. Engineers Opinion of Cost for Motorist Assistance and Safety Services

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Standard MAP Specification - One-Time Consultant Fee	Scope	$30,000	-	$30,000
CRASH Vehicles - 20 Vehicles at $90,000 Per Vehicle	Scope	-	$360,000	$1,800,000
Enhance Field Communications with Phoenix District via 800 MHz Radios - 50 Units at $1,500 Per Unit Installed	Scope	$75,000	-	$75,000
ADOT VHF Radios in DPS Vehicles - 440 Units at $1,500 Per Installation - Total $660,000: All Costs by DPS	Scope	-	-	$0
District Training Programs - Consultant Fees for Protocol Updates	Field	-	$8,000	$40,000
TOTAL	**-**	**$105,000**	**$368,000**	**$1,945,000**

13. INFORMATION SHARING:

IMPLEMENTATION PLAN

This chapter details the proposed plan to integrate numerous state-of-the-practice ITS deployment concepts for information sharing into a set of project implementation recommendations that address both project goals and stakeholder needs.

Each concept discussion includes an engineer's opinion of probable cost over a five-year life cycle based on capital expenditures, on-going operations and maintenance costs, recommended staffing, ongoing utility costs and/or designated consultant fees. The proposed concepts in the information sharing focus area are:

- Oversized Load Management.
- Simulator Interagency Training.
- Internal Information Sharing.

13.1 OVERSIZED LOAD MANAGEMENT

A key potential ITS deployment concept in this focus area would coordinate oversize and overweight permit-management operations on major corridors throughout the state, most notably in the southern regions. As described in Chapter 8, significant concerns exist regarding interstate and intrastate movement of loads that exceed weight, height and length restrictions. The ADOT Motor Vehicle Division issues all permits for vehicles bearing excessive loads on Arizona highways, requiring the use of specific routes based on load characteristics, qualified escort services, and authority notifications.

This concept is a recommendation for a new ITS research program to identify a suitable GPS-based AVL data system as a tracking and mapping tool for ADOT users to monitor the progress of oversized vehicle movement on Arizona's highways. Individual portable transmitter units would be placed in or on the transport vehicle (not the escort vehicles) at the point of origin. Being able to track vehicle movement throughout the state will assist ADOT traffic and maintenance engineers in assessing routes, making sure that the oversized dimensions and weights do not exceed existing highway design limitations.

At the ports of entry or mobile weigh stations, each oversized vehicle will be outfitted with a wireless transmitter and GPS receiver to transmit its location data using satellite communications. With real-time transmission service, this GPS-AVL location data will be delivered to the oversized vehicle data assessment system.

Three servers are used for this proposed concept. The first server will process the GPS data and compute vehicle coordinates. The second server uses this data to generate maps. The third server populates the maps with the location and route tracking status for the oversized vehicle. This allows ADOT to track vehicle movement and assess progress along the designated permit route. All three servers work together using specialized client/server software that can be accessed through a web browser in remote applications.

Custom software can identify specific vehicle characteristics, with location logging and playback, incorporating other available data sets to generate a website capture of progress and updates. The software can be designed to cross-reference other statewide databases, such as the Highway Condition Reporting System, 511 system, and any others to flag specific issues as they develop. With the current condition of highways changing on a daily, sometimes hourly basis due to construction or maintenance activity, potential conflicts can be flagged prior to any physical damage occurring.

When this plan is fully implemented, the individual transmitters would be supplied by the trucking industry as a mandatory requirement for travel on Arizona highways. Data on individual vehicles would be logged at ports of entry or mobile weigh stations and downloaded to the database server, which would be maintained by MVD. The ADOT, MVD, and DPS agencies would share access to specific data within the database as needed, through remote applications using a web browser. The software could also prompt system users to deploy suitable route-restriction messages on Dynamic Message Signs and Highway Advisory Radios, as available.

Concept Benefits and Challenges

This ITS concept allows ADOT to identify potential conflicts before any physical damage is done to the state's infrastructure. This concept also can help identify offenders and assess damages to the third party for compensation. Potentially, this concept can save the state millions of dollars associated with infrastructure repairs and rebuilds.

The user interface would allow remote access to databases and on-the-fly assessment of particular oversized vehicle movement on almost any highway. The time savings for users would allow for a more rapid assessment of the oversized vehicle route, freeing up time for other permitting tasks.

A potential challenge for deployment of this concept is resistance by the trucking industry. Specialized electronic systems are in use at some ports-of-entry across the country, which allow pre-qualified vehicles to bypass those checkpoints. The DOTs must frequently remind system users that speed is not being recorded, and that individual movement is not being tracked. There is an aversion by the industry to monitoring systems, especially automated ones. Another major challenge will be requiring the trucking industry to finance the individual AVL units for tracking of the oversized vehicles. With over 14,000 Class C permits issued per year, a number that has been increasing in recent years, this would require a high capital expenditure.

Specialized software must be created to receive data and maintain a database. Additional software would be needed to mine the database and to plot appropriate information on specialized maps, based on user-defined inputs. This concept represents a high capital cost for a single state DOT to initiate software development, integration, and long-term resource maintenance; Federal efforts in this area may eventually offer practical options.

Concept Implementation and Cost Breakdowns
The need for oversized vehicle management was identified in the southern region through field interviews. The opinion of total cost for this concept is $400,000. The cost to conduct stakeholder interviews, define requirements, and develop a Request for Proposal is estimated at $75,000. The cost to develop customized software and acquire initial hardware is estimated at $250,000. The cost to generate an industry outreach campaign is estimated at $50,000. The cost for initial implementation and evaluation is $25,000.

13.2 SIMULATOR INTERAGENCY TRAINING

This recommendation focuses on snowplow simulator training, for which ADOT's Local Technical Assistance Program (LTAP) may provide limited resources for qualified third-party trainers through local joint agreements. ADOT has an established training program that has expanded over three years to include these driving simulators in several districts.

Concept Benefits and Challenges
This concept offers a consistent program that can be in-place and utilized year-round for participating agencies. With a consistent training program, other agencies can reduce the impacts of high turnover rates among their snowplow operators from season to season. However, as the District operator-trainers are typically limited in their availability for additional support, joint training sessions would not be realistic. A possible solution would be to use third-party simulator trainers for joint training sessions.

Concept Implementation and Cost Breakdowns
This concept was identified through field interviews. In offering these capabilities to other local public agencies, ADOT would require full funding by those partner agencies for their personnel's safety- and efficiency-related training courses. This could include the entire cost of the training classes, facilities, and third-party training staff, and it is not included in the budget estimates for this concept.

The cost to ADOT for this concept is only for LTAP's training coordination activities. The opinion of cost for this concept is $12,000 annually for supplemental coordination efforts to assist the partner agencies to establish timely training programs in preparation for the winter storm seasons, for a total of $60,000 over five years.

13.3 INTERNAL INFORMATION SHARING

This concept encompasses networking for District staff members by attending professional meetings and conferences, Department workshops and conferences, and taking specialized training. Many such programs regularly offer opportunities to ADOT personnel for professional development and information sharing, including:

- ADOT Maintenance Servant Leadership Team (MSLT) Bi-monthly Meetings.
- ITS America: Annual National Conference.
- ITS Arizona: Annual Conference, and Quarterly Member Meetings.
- Institute of Transportation Engineers (ITE) Technical Conference (Annual Joint Meeting with IMSA), and Monthly Section Meetings.
- The Consortium for ITS Training and Education (CITE) Conference.
- The Roads and Streets Conference sponsored by the Arizona Chapter of the American Council of Engineering Companies (ACEC).
- ADOT Winter Maintenance Conference (LTAP and ADOT Technical Training).
- ADOT Maintenance Training Workshop.
- Rural ITS Annual National Conference.
- Transportation Research Board Annual National Meeting.

Participants should embrace these opportunities to meet and coordinate time to review ITS developments in their respective areas of influence and discuss recent, planned and future deployments of ITS services.

For individual reference materials, there are numerous periodicals, newsletters and websites that offer up-to-date reports of technology advancements, ITS services deployments, and other agency experiences with ITS services. Participants are encouraged to review the material as it becomes available. As the material is typically available on-line or supplied with conference registration or society enrollment, associated costs are negligible and participants would only need to devote minimal time for reading. The list of available materials includes, but is not limited to:

- ITS Arizona Quarterly Newsletter and Website.
- ITE Quarterly Newsletter and Website.
- ADOT Monthly E-Newsletter TRANSend, at: (http://www.azdot.gov/CCPartnerships/TRANsend/Index.asp)
- ADOT-ATRC Research Project Reports, Quarterly Newsletters, Implementation Reports, Emphasis Area Workshops.

Concept Benefits and Challenges

By keeping abreast of the latest industry offerings, as well as relevant neighboring agency experiences, ADOT field personnel can assess new ITS services and decide if their applications might benefit the District. As with any industry, actively taking part in professional societies and reviews of research is a time-critical task, and many of the district representatives noted that their current workload doesn't allow time to read or to travel elsewhere for conferences.

Concept Implementation and Cost Breakdowns

This recommended concept addresses an original project goal. The costs to ADOT for attending various conferences can range from free to several hundred dollars, not including travel expenses. The opinion of cost for this concept is $50,000 annually, to allow $500 in registration, travel and lodging expenses for 20 ADOT individuals each to attend five conferences per year (100 such person-trips annually overall), for a total of $250,000 over five years. Participants would vary by conference focus, but could include District Engineers, the maintenance, construction and traffic staff engineers, maintenance supervisors, and field technicians.

13.4 INFORMATION SHARING CONCEPTS SUMMARY

The proposed ITS concepts for this focus area are summarized below in Table 17, including the engineer's opinion of cost for each concept.

Table 17. Engineers Opinion of Cost for Information Sharing Concepts

Deployment Concept	**Project Goal**	**Initial / Capital Costs**	***Annual* Operating & Maintenance Costs**	**Opinion of Cost (*Over 5 Years*)**
Oversized Load Management - Initial Implementation of System - System Expansion and On-Going Costs Absorbed by Industry Agencies	Field	$400,000	-	$400,000
Simulator Interagency Training - Supplemental Activities Required for Establishing Coordination with Partner Agencies	Field	-	$12,000	$60,000
Internal Information Sharing - 5 Conferences Per Year, for 20 Participants	Scope	-	$50,000	$250,000
TOTAL	**-**	**$400,000**	**$62,000**	**$710,000**

14. RESULTS AND RECOMMENDATIONS

Project Results and Estimated Implementation Costs

This ITS research has identified numerous concepts that can be implemented to address the basic project goals in five broad focus areas: ITS maintenance, weather information systems, traveler information systems, motorist assistance and safety, and information sharing. The concepts are presented with initial capital costs, plus any associated annual costs; each recommended concept has an associated five-year cost of implementation. The costs for each individual proposed concept are summarized in Table 18. The five-year sum of recommended costs for each ITS focus area is then presented in Table 19.

Table 18. Engineers Opinion of Cost for Rural ITS Concepts

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Focus Area: ITS Maintenance				
Third-Party ITS Operations & Maintenance Contracting - $200,000 Annual Contract	Scope	-	$200,000	$1,000,000
Truck Escape Ramp Monitoring - 7 Sites at $125,000 Per Site (Total)	Field	$700,000	$35,000	$875,000
Expansion of Rural Cellular Coverage - Major US & State Route Coverage	Scope	$75,000	-	$75,000
DMS Construction - 8 Sites at $312,500 Per Site (Total)	Scope	$2,300,000	$40,000	$2,500,000
Focus Area: Weather Information Systems				
Participation in Clarus - Database Development & Maintenance, Coordination with National Agency	Scope	-	$100,000	$500,000
RWIS Deployment - 48 Sites at $112,000 Per Site (Total)	Scope	$768,000	$921,600	$5,376,000
State Meteorologist - 1 Position at $85,000 Annual Salary	Field	-	$85,000	$425,000
Low Cost Weather Stations - 40 Sites at $2,500 Per Site (Total)	Scope	$64,000	$7,200	$100,000
Low Visibility Detection - 15 Sites at $75,000 Per Site (Total)	Field	$900,000	$45,000	$1,125,000
Bridge Deck Anti-Icing Monitoring - 3 Locations at $100,000 Per Site (Total)	Field	$240,000	$12,000	$300,000
Develop IGAs for Flood Detection - 11 County Agencies: $70,000 IGA	Field	$770,000		$770,000

Deployment Concept	Project Goal	Initial / Capital Costs	*Annual* Operating & Maintenance Costs	Opinion of Cost (*Over 5 Years*)
Mobile Data Collection for Snowplows - 54 Snowplows at $12,000 Per Vehicle (Total), with satellite communications.	Field	$540,000	$21,600	$648,000
Focus Area: Traveler Information Systems				
Portable HAR – 8 Units at $30,000 Each (Total)	Scope	$200,000	$8,000	$240,000
Work Zone HAR Specifications Development - One-Time Consultant Fee	Scope	$5,000	-	$5,000
Permanent HAR Sites - 20 Sites at $25,000 Per Site (Total)	Scope	$400,000	$20,000	$500,000
Intelligent Rest Area Deployment - 15 Sites at $48,000 Per Site (Total)	Scope	$645,000	$15,000	$720,000
Corridor Travel Time Monitoring - 8 Sites at $112,500 Per Site (Total)	Field	$800,000	$20,000	$900,000
Emergency Detour Routing - 33 EMS at $6,000 Per Sign (Total)	Field	$148,500	$9,900	$198,000
Focus Area: Motorist Assistance and Safety Services				
MAP Specification Development - One-Time Consultant Fee	Scope	$30,000	-	$30,000
CRASH Vehicles - 20 Vehicles at $90,000 Per Vehicle	Scope	-	$360,000	$1,800,000
Enhanced Field Communications with Phoenix District via 800 MHz Radios - 50 Units at $1,500 Per Unit Installed	Scope	$75,000	-	$75,000
ADOT VHF Radios in DPS Vehicles - 440 Units at $1,500 Per Installation - Total $660,000: All Costs by DPS	Scope	-	-	$0
District Training Programs - Consultant Fees for Protocol Updates	Field	-	$8,000	$40,000
Focus Area: Information Sharing				
Oversized Load Management - Initial Implementation of System - System Expansion and On-Going Costs Absorbed by Industry Agencies	Field	$400,000	-	$400,000
Simulator Interagency Training - Supplemental Activities Required for Establishing Coordination with Others	Field	-	$12,000	$60,000
Internal Information Sharing - 5 Conferences Per Year, for 20 Participants	Scope	-	$50,000	$250,000

Table 19. Total Engineers Opinion of Cost for Rural ITS Concepts

Focus Areas Deployment Concepts	Opinion of Cost
ITS Maintenance	$4,450,000
Weather Information Systems	$9,244,000
Traveler Information Systems	$2,563,000
Motorist Assistance and Safety Services	$1,945,000
Information Sharing	$710,000
TOTAL OVER 5 YEARS	$18,912,000
AVERAGE TOTAL COST PER YEAR	3,782,400

Project Priority Recommendations

The ITS concepts developed by this project were reviewed and prioritized by the Technical Advisory Committee (TAC). Each member of the TAC was asked to identify the level of priority (high, medium, low) for each ITS concept within each focus area. In addition, they were requested to identify potential process owners (or project champions) for each ITS concept. Lastly, each TAC member suggested potential resources for the deployment of the individual concepts.

Table 20 indicates which ITS concepts the TAC recommends for further development; who within the Department will champion the concepts; and what potential resources are identified for funding. Some ITS elements of future projects may be eligible for regular Federal-aid construction funding, and these are asterisked in the "Resources" column. The TAC's consensus on prioritization of these ITS concepts is also indicated.

Table 20. Prioritization of Rural ITS Concepts

Deployment Concept	Project Goal	Priority	Potential Process Owner(s)	Identified or Potential Resources for Deployment
Focus Area: ITS Maintenance				
Third-Party ITS O&M Contracting	Scope	High	TTG	TTG Funds
Truck Escape Ramp Monitoring	Field	Med	TTG or Districts w/ Ramps	TTG and District Minor Funds*
Expansion of Rural Cellular Coverage	Scope	Med	Right-Of-Way Section	ITD Funding
DMS Construction	Scope	High	TTG / District	TTG or District Minor*
Focus Area: Weather Information Systems				
Participation in Clarus	Scope	High	TTG	TTG Funds*
RWIS Deployment	Scope	Med	TTG or Central Maintenance	TTG and District Minor Funds*
Highway-Focused State Meteorologist	Field	High	TTG	Cost Share Each District
Low Cost Weather Station Deployment	Scope	Med	Central Maintenance	District Minor Funds*

Deployment Concept	Project Goal	Priority	Potential Process Owner(s)	Identified or Potential Resources for Deployment
Low Visibility Detection	Field	Med	TTG or District	District Minor or HES*
Bridge Deck Anti-Icing Monitoring	Field	Low	District	District Minor or HES*
IGAs for Flood Detection	Field	Med	State Maintenance Engineer	Maintenance Fund
Mobile Data Collection for Snowplows	Field	Med	Equipment Services	Districts and Equipment Services
Focus Area: Traveler Information Systems				
Portable HAR	Scope	Med	District	Construction Fund or District Minor*
Work Zone HAR Standard Specifications	Scope	Med	CCP	CCP Fund or State Construction Fund*
Permanent HAR	Scope	High	District	District Minor or Maintenance Fund*
Intelligent Rest Area Deployment	Scope	Low	Roadside Development	Construction Fund (Rest Area Fund)*
Corridor Travel Time Monitoring	Field	High	TTG or Districts	TTG Fund*
Emergency Detour Routing	Field	High	TTG or Districts	TTG Fund
Focus Area: Motorist Assistance and Safety Services				
Standard MAP Specification	Scope	Med	TTG or Districts	TTG Fund*
CRASH Vehicles	Scope	Med	Districts and Equipment Services	State Engineers Office and District Funds for Equipment Services
Enhanced Communication w/ Phoenix Maintenance via 800 MHz Radios	Scope	Med	Central Maintenance	Maintenance Fund
Secondary ADOT UHF Radios for DPS	Scope	Med	DPS	DPS
District Training Programs	Field	Med	State Maintenance Engineer	Maintenance Fund
Focus Area: Information Sharing				
Oversized Load Management	Field	Med	Regional Traffic Engineers	Maintenance Fund
Simulator Interagency Training	Field	High	Districts and LTAP	LTAP and Third Party Funds
Internal Information Sharing	Scope	High	TTG	ITD & District Funds

*Some ITS elements of projects as noted may be eligible for regular Federal-aid construction funding.

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