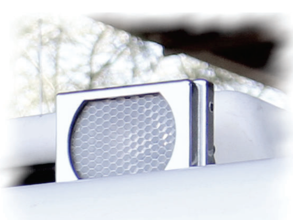
MARICOPA ASSOCIATION of GOVERNMENTS



Maricopa Association of Governments (MAG)

Emergency Vehicle Preemption State of the Practice Study

Final Report

August 2016

Table of Contents

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Maricopa Association of Governments (MAG) Emergency Vehicle Preemption State of the Practice Study

The Maricopa Association of Governments (MAG) conducted a comprehensive study regarding current Emergency Vehicle Preemption (EVP) practices in the MAG region. This report summarizes the findings of the study and is organized into four sections. Section 1, Regional EVP Inventory and Operational Challenges, describes the state of EVP deployment in the MAG region and associated emergency response automatic or mutual aid operations issues. Section 2, Review of EVP Technologies, provides a review of the current and emerging EVP technologies. Section 3, Case Studies, describes relevant practices around the nation that could benefit the MAG region. Section 4, Future Considerations, provides potential recommended practices to improve the interoperability, consistency, and operational coordination across the MAG region.

Emergency Vehicle Preemption is accomplished by adjusting traffic signal phasing, initiated through communications between a receiving device installed on a traffic signal and an emitter on an approaching emergency vehicle, to facilitate safe passage for the emergency vehicle through the intersection. Emergency vehicles equipped with an emitter can request traffic signal preemption treatment as they approach an instrumented intersection. Several jurisdictions in the MAG region began installing EVP systems shortly after the introduction of EVP technology in early 1980s. With a goal of reducing response times, EVP capability is widely considered by first responders and transportation agencies as an essential function of traffic signal operations in urban areas.

While the Manual on Uniform Traffic Control Devices (MUTCD) specifies the standards for transitioning into and out of preemption, there is a lack of guidance in the critical aspects regarding EVP operations, including preemption signal phase, confirmation light, data encryption, and the needed inter-agency coordination in support of emergency response automatic or mutual aid agreements. The distinction of inter-agency support is important. The Valley Wide Automatic Aid system ("automatic aid") involves centralized dispatch by Phoenix Alarm resulting in the nearest emergency resource, regardless of agency and geographical boundaries, responding to the event. Mutual aid agreements are established such that agencies will support each other upon request. This MAG EVP State of the Practice Study intends to address these knowledge gaps by identifying priority issues and recommending feasible approaches toward improved regional coordination.

1. REGIONAL EVP INVENTORY AND OPERATIONAL CHALLENGES

1.1 Overview of EVP Systems in MAG Region

The EVP currently deployed within the MAG region are optical-based systems using technology originally introduced in the late 1970's by 3M. By 1990, EVP was widely endorsed by the emergency response community as an effective tool for reducing response time, improving safety of emergency vehicle operations, addressing risk management, savings in fire/rescue and EMS planning, and savings on fire insurance premiums[1]. Several jurisdictions[2] in the MAG region began implementing EVP systems in 1980's funded primarily by public safety funds.

The optical-based EVP system consists of onboard vehicle emitters and traffic signal components: optical detectors, preemption detector cards and optional confirmation lights. Figure 1 illustrates the basic components of an optical-based EVP system.

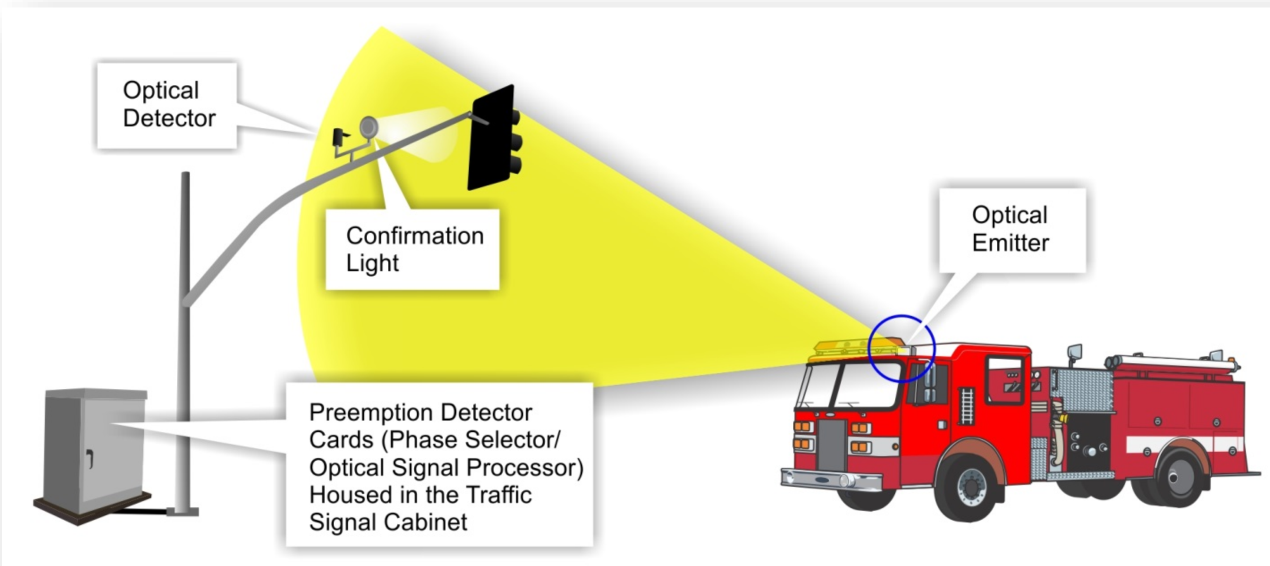


Figure 1. Basic Components of the Optical-Based EVP System

A general description of each EVP system component is provided here as part of the overview.

[1] Traffic Signal Preemption for Emergency Vehicles Traffic Signal Preemption for Emergency Vehicles, A Cross-Cutting Study, FHWA, Page 3-1, January, 2006

[2] The early adopters of EVP in the MAG region included the Cities of Tempe, Mesa, Scottsdale and Chandler.

Optical Emitter

The optical emitter is typically mounted on top of the emergency vehicle. When activated, the emitter produces an infrared strobe signal at a pre-programed frequency that can be received by the optical detectors on the traffic signal mast arm. The vehicle emitter typically operates at a constant maximum intensity level that can be detected up to approximately 2,500 feet[3]. The actual detection range can be set by adjusting the intensity thresholds on the preemption detector card housed in the traffic signal cabinet. In general, the detection range is predicated on the amount of time needed for an emergency vehicle to arrive at the intersection as well as the minimum time required to transition from the current traffic signal timing plan to the special preemption mode. Figure 2 shows the optical emitter installed on a City of Tempe fire engine.

Figure 2. EVP Emitter Installed on a City of Tempe Fire Engine

The emitter is typically wired to the gearshift of the vehicle and/or the vehicle door switch that will turn off the emitter when the vehicle's parking break is engaged or door is opened. This configuration prevents continuous actuation from a parked vehicle within the range of a detector.

EVP emitters can be encoded with an assigned ID. The primary purpose of encoding is to prevent the unauthorized and illegal activation of EVP by drivers using rogue devices. The embedded ID code is transmitted in the optical signal that is read and recorded by the roadside equipment for monitoring usage.

[3] The maximum range of an EVP emitter may vary by mounting height, vertical and horizontal alignments with the optical detector, atmospheric condition, deterioration of the detector and emitter, obstructions to the line of sight (e.g., vegetation), etc.

Optical Detector

The traffic signal component of the EVP system includes the optical detectors and the (optional) confirmation lights on the traffic signal mast arm, and the preemption detector cards housed in the traffic signal cabinet. The optical detector is made up of a light-gathering sight tube that contains a lens, and a photodiode (light sensor) housed within the cylinder-shaped unit. Figure 3 shows common configurations of optical detectors in the MAG region.

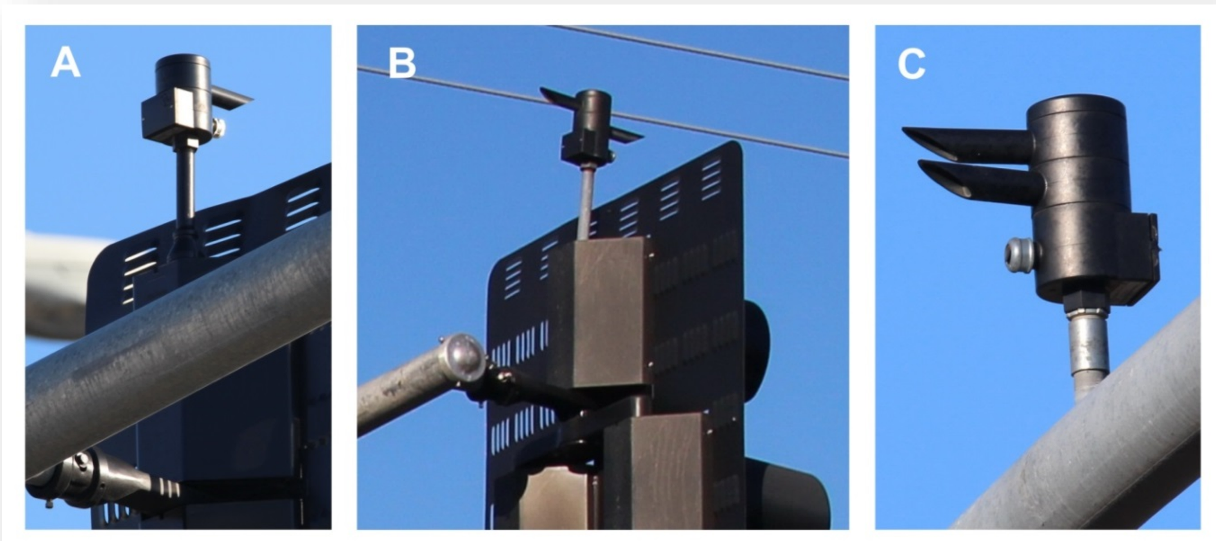


Figure 3. Examples of EVP Optical Detectors in the MAG Region

Picture A of Figure 3 shows a detector unit mounted on the back of a traffic signal head (City of Mesa). Picture B shows the detector unit with two sight tubes aiming at the opposite approaches (City of Mesa). The rationale for combining two detectors in a single unit is to reduce the amount of wiring within the mast arm and the underground conduits which are often crowded with traffic signal-related electrical cables. Picture C shows two sight tubes pointing in the same direction at slightly different angles to provide wider coverage of an approach (City of Chandler). This configuration is also used on curved roads to cover both the near and far fields of the approach to compensate for the line of sight limitations of the optical-based detection. The two sight tubes may be configured on different channels or on the same channel per specific applications.

Confirmation Light

The primary purpose of the confirmation light is to provide preemption status feedback to the emergency vehicle operator. As the controller transitions from scheduled operation into preemption operation, the confirmation light is activated for the approaching emergency vehicle. This feature is especially important when more than one emergency vehicle is requesting signal preemption from conflicting directions. As an ancillary benefit, the confirmation light advises the general public to act with caution as the intersection is being preempted for an approaching emergency vehicle. The confirmation light is usually installed adjacent to the optical detector on the signal mast arm.

Figure 4 shows two variations of the EVP confirmation light in the MAG region. The City of Phoenix (Picture A of Figure 4) has deployed one (white) confirmation light for each approach. A steady light indicates the direction that the emergency vehicle is approaching from. In the case of multiple preemption requests, a flashing light informs the emergency vehicle operator that their right-of-way has been denied due to a competing preemption request from a conflicting approach. The City of Apache Junction (Picture B of Figure 4) uses two strobe lights of differing color to indicate the direction of the emergency vehicle (e.g., blue indicates east-west, white indicates north-south direction). These strobe lights can be seen from all approaches of the intersection.

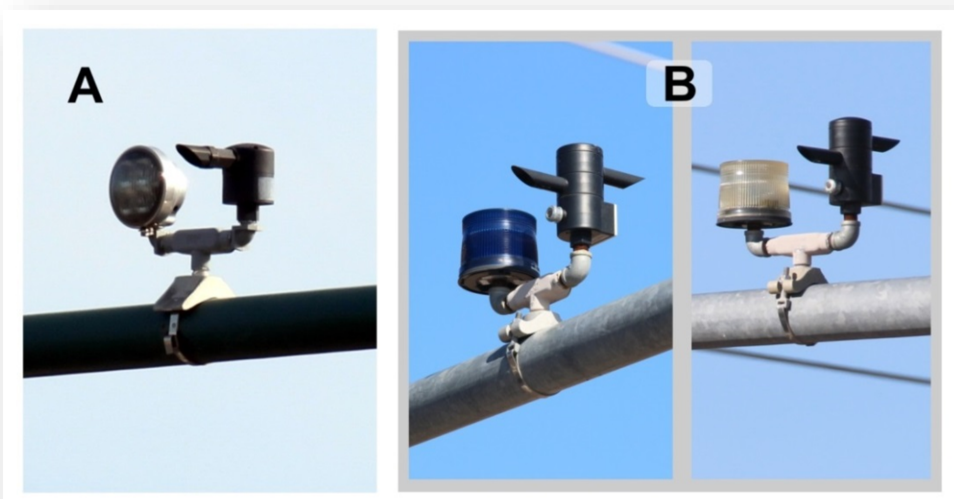


Figure 4. Different Confirmation Light Configurations in MAG Region

Preemption Detector Card

The preemption detector card, in the form of an electronic board, is housed in the traffic signal cabinet. When the optical detector on the mast arm receives the request from an approaching emergency vehicle, the infrared signal is processed by the preemption detector card. If encoding is used, the preemption detector card will verify the ID code embedded in the signal to determine if it is within the range of permitted IDs (programmed on the preemption detector card). To grant the preemption request, the preemption detector card examines the intensity level of the signal (correlated to the distance of the emergency vehicle). If the intensity level exceeds a pre-programmed threshold[4], the detector card would make a preemption call to the traffic signal controller to begin the transition from the current signal phase to the special preemption mode. Figure 5 shows an example of the preemption detector cards housed in the traffic signal cabinet at an intersection in the City of Tempe.

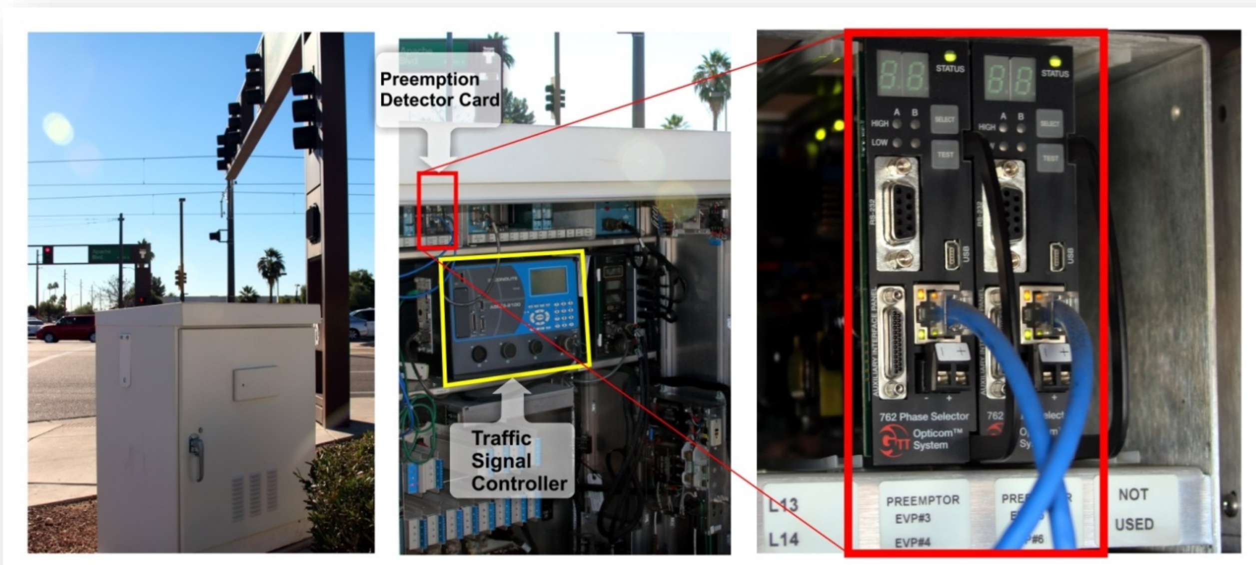


Figure 5. Example of Preemption Detector Cards in a City of Tempe Traffic Signal Cabinet

Figure 5 shows that two two-channel preemption detection cards (4 channels total) are used at the location. Each channel corresponds to an optical detector on the mast arm which allows the

[4] The intensity level (range) is set by positioning an emitter (e.g., mounted on a truck) from a desired distance to the detector. The traffic signal technician at the traffic signal cabinet records the intensity value on the corresponding preemption detector card. This process is referred to as setting detection range.

system to differentiate the direction of the preemption request. First-come, first-serve[5] applies when there are multiple preemption requests coming from the conflicting approaches.

The traffic signal controller takes input from the preemption detector cards and transitions the traffic signal from the current timing plan to pre-defined preemption signal phases. The preemption signal phase provides right-of-way to the approaching emergency vehicle and prohibits traffic from conflicting approaches.

1.2 EVP Inventory Survey Results

Information regarding EVP implementation was obtained from the following agencies using a combination of survey, personal and telephone interviews:

- Apache Junction
- Avondale
- Buckeye
- Chandler
- El Mirage
- Fountain Hills
- Gila River Indian Community
- Gilbert
- Glendale
- Goodyear
- Maricopa
- Mesa
- Paradise Valley
- Peoria
- Phoenix
- Scottsdale
- Surprise
- Tempe
- Tolleson
- Queen Creek
- Maricopa County
- Pinal County
- Arizona Department of Transportation (ADOT)
- Valley Metro

Unlike the cities, ADOT's EVP deployment has been limited to freeway interchanges that are managed by local jurisdictions through an Inter-Governmental Agreement (IGA). The EVP configuration is therefore determined by the managing jurisdiction. Valley Metro is included in this study as they are using the low priority request feature of the EVP system to provide Traffic Signal Priority[6] (TSP) to the LINK Bus Rapid Transit (BRT) services in Mesa, Chandler and Gilbert.

[5] Older preemption detector cards do not communicate with one-another. The arbitration between conflicting preemption calls is handled by the traffic signal controller which has an input for each direction of requested priority. With a 4-channel 700 series GTT detector card, relative priority is a function in the phase selector settings.

[6] Buses use an emitter configured in a low-priority mode that are over-ridden by emergency vehicles. The bus only activates a request for service if it is on-time or behind schedule. The intersection either provides an early or extended green indication to facilitate the passing of the approaching bus. Unlike preemption, TSP does not typically cause the traffic signal to transition to get back into coordination with adjacent signals. This only occurs under full preemption status. Transition varies depending on controller software and agencies' policies.

The key information solicited in the regional survey included:

- Number of EVP equipped intersections (out of total signalized intersections)
- Brand of EVP system deployed
- Signal phase provided during preemption
- Confirmation light configuration
- Use of encoding
- Other jurisdictions coordinated for encoding
- Detection range settings (typical)
- Maintenance practices
- Funding (hardware, maintenance)
- Users (fire, ambulance, police)
- Management of EVP systems using the Central Software
- Review of usage data
- Shared use with transit Traffic Signal Priority (TSP) applications

Table 1 provides a summary of key EVP implementation characteristics in the MAG jurisdictions. Although this study does not advocate a specific vendor's product, the brands of EVP systems deployed by the individual jurisdictions are of interest from the perspective of system compatibility in support of automatic or mutual aid agreements. The two EVP products deployed in the MAG region are made by Global Traffic Technologies (GTT) and TOMAR Electronics. GTT (formerly 3M as of 2009) marketed its optical-based EVP system as Opticom©. TOMAR Electronics branded its optical-based EVP product as STROBECOM©. Although the two products work in a similar way, the proprietary encoding scheme employed by each product is a source of incompatibility should a jurisdiction choose to encode the EVP system.

There are other EVP products in the market, such as EMTRAC, but as there are no other systems deployed in the MAG region, these products are not detailed in this study.

Table 1. Summary of EVP Implementation in the MAG Region

Jurisdictions (Traffic Signal Contracted to)	# of EVP Intersect ions (Total Signalized)	Brand (GTT, TOMAR)	Encoding (Y/N)	Signal Phase Provided (B, B+A)[7]	Confirmation Light (2, 4-way)[8]	Detection Range (Feet)	Main-tenance Period	Users (Fire, EMT, Police)	Review Usage Data[9]	Transit Low Priority (Y/N)
Apache Junction	26 (32)	G	Y	B+A	2-way	2500	3 mo	F[10], E	Reactive	N
Avondale	40 (47)	T	N	B+A	4-way[11]	1000	3 mo	F, E	Reactive	N
Buckeye	11 (16)	G	N	B+A	N/A	2600	Annual	F, E, P	Reactive	N
Chandler	201 (216)	G	Y	B	N/A	2600	Annual	F, E	Reactive, TransSuite	N
El Mirage	7 (12)	G, T	N	B	2-way	200	Annual	F, E	Reactive	N
Fountain Hills	13 (13)	G	Y	B+A	N/A	Max	6 mo	F, E	Reactive	N
Gila River Indian Community (MCDOT)	5 (7)	G, T	N	B+A	N/A	250	6 mo	F	Reactive	N
Gilbert	175 (181)	T	N	B+A	N/A	1000	2 mo	F, E, P	Centracs	Y
Glendale	13 (194)	T	N	B+A[12]	N/A	200-2500	Annual	F	CMS[13], KITS	N
Goodyear	46 (82)	G	Y	B+A	N/A	790-1180	Annual, 2 mo	F, E, P	Reactive	N
Maricopa[14]	4 (15)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N

Note: The survey was conducted during fall of 2015. Some of the information may have changed since then.

[7] B indicates a green ball for both opposing through movements for permissive and protected left-turn locations; B+A represents a green ball and green arrow for protected left-turn locations.
[8] Type of confirmation light: 4-way directional flood light, 2-way strobe light, N/A – not deployed. Confirmation light presence can only account for some locations and does not include every signal within the jurisdiction.
[9] Indicates how EVP usage data is reviewed: Reactive – field data download in response to trouble calls, CMS – GTT Central Management Software, TransSuite, Centracs, KITS, Intelight Maxview are the central traffic signal management software capable of logging preemption events.
[10] Only some fire engines are equipped with an emitter.
[11] Confirmation lights are not deployed at all EVP equipped intersections.
[12] Raised median island – green ball and arrow; No island – green ball for both through movements.
[13] Glendale has the software but it is not actively used.
[14] Maricopa has installed hardware at four intersections but it is not configured for operations. No emitter was purchased.

Jurisdictions (Traffic Signal Contracted to)	# of EVP Intersect ions (Total Signalized)	Brand (GTT, TOMAR)	Encoding (Y/N)	Signal Phase Provided (B, B+A)[7]	Confirmation Light (2, 4-way)[8]	Detection Range (Feet)	Main-tenance Period	Users (Fire, EMT, Police)	Review Usage Data[9]	Transit Low Priority (Y/N)
Mesa	349 (425)	G	Y	B, B+A[15]	N/A	1800	Reactive	F, P[16]	CMS, Centracs	Y
Paradise Valley (City of Phoenix)	12 (12)	T	N	B	4-way	1500	Annual	F, P	N	N
Peoria	111 (115)	G	N	B	N/A	1500	3 mo	F	CMS[17], Intelight MaxView	N
Phoenix	243 (1138)	T	N	B	4-way	2500	Annual	F	Reactive	N
Scottsdale	223 (300)	G	N	B	N/A	1500	Annual	F, E	TransSuite	N
Surprise	50 (50)	T	N	B+A	2-way[18]	500-1000	Reactive	F, E, P[19]	Reactive	N
Tempe	230 (230)	G	Y	B	N/A	1000	6 mo	F, A	CMS, TransSuite	N
Tolleson (Avondale)	4 (10)	T	N	B+A	4-way	500	3 mo	F, A	Reactive	N
Queen Creek	28 (41)	T	N	B	N/A	2500	Routine	F	Reactive	N
ADOT	-	-	-	-	-	-	-	-	-	
MCDOT	40 (170)	T	N	B+A	Vary	1500	Annual	F	Reactive	N
Pinal County[20]	12 (26)	G	N	B	4-way	N/A	N/A	N/A	N/A	N
Valley Metro	40	G	Y	-	-	800	-	-	-	Y

[15] Half of Mesa's EVP intersections have green ball plus green arrow for the preempted direction at protected left turn locations, and the other half have been converted to green ball for both through movements at the protected left-turn locations.
[16] Mesa is conducting an experiment involving 12 police vehicles.
[17] Peoria initially used Central Management Software. After traffic signal management software upgrade, started relying on the logs of the Intelight MaxView ATMS system.
[18] Surprise only installed the confirmation light at some of the intersections. The confirmation lights are not configured to work as of the time of survey.
[19] Surprise plans to include police as EVP users in 12 months.
[20] Pinal County has installed but not configured its hardware. No emitter was purchased.

Level of EVP Implementation

Among the 21 jurisdictions that responded to the survey, 1,920 out of 3,332 (57.6%) signalized intersections are equipped with EVP. Figure 6 shows the percentage of signalized intersections equipped with EVP, by jurisdiction.

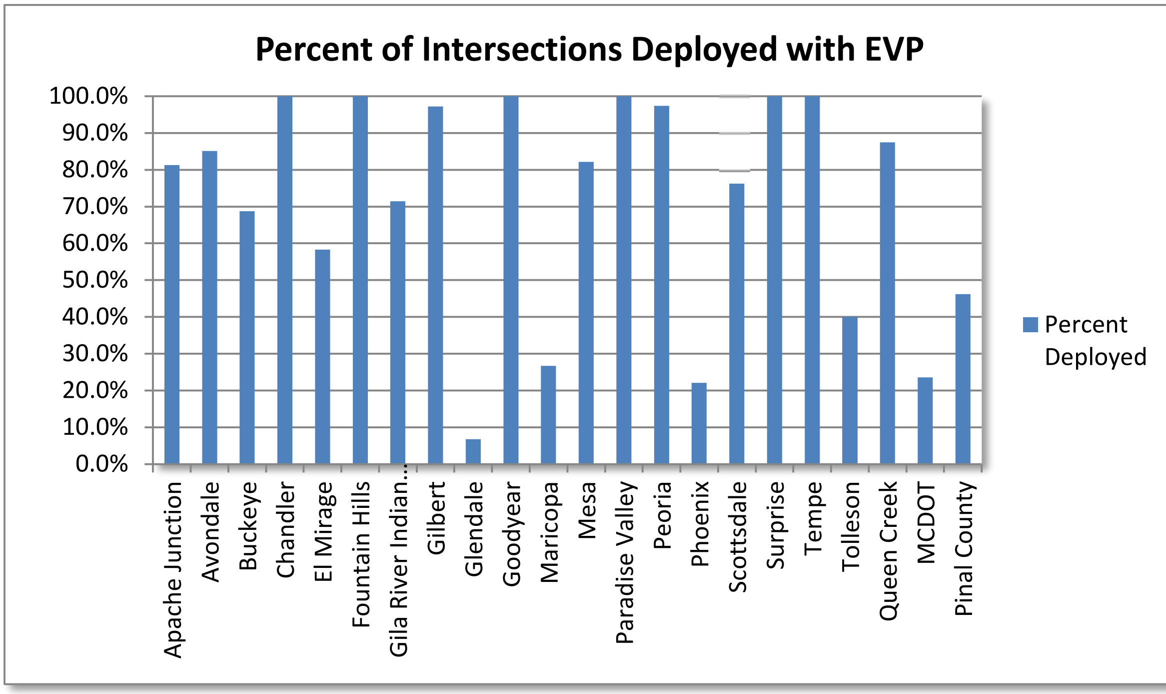


Figure 6. Percentage of Signalized Intersections Equipped with EVP

Encoding by Type of EVP System

Eleven agencies with a total of 1,309 (68.2% of all EVP equipped locations) intersections deployed the GTT system. Nine agencies with a total of 611 (31.8%) intersections are equipped with the TOMAR system. Two jurisdictions with a total of 13 (0.6%) intersections deployed both GTT and TOMAR systems. None of the TOMAR (11) systems deployed in the region are encoded. Figure 7 shows the percentage of intersections by system type and encoding. The un-encoded system is denoted as open.

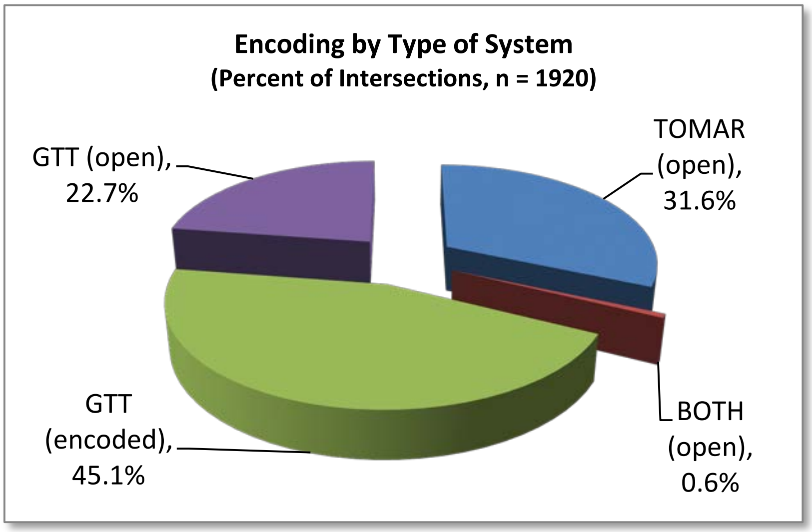


Figure 7. Encoding by Type of System

Among the encoded jurisdictions, Mesa, Chandler, Tempe, Apache Junction and Fountain Hills employed the coding scheme developed by the East Valley EVP Working Group. These jurisdictions not only can activate preemption in each other's jurisdiction, the uniquely assigned vehicle emitter ID can be captured for system monitoring and usage data analysis. Goodyear (GTT) is the only jurisdiction in the West Valley that encodes its EVP system. An encoded EVP system in a city would lock out all TOMAR and un-encoded GTT emitters employed by neighboring cities. The City of Gilbert has an un-encoded TOMAR system at the intersections but equips the emergency vehicles with an encoded GTT emitter. This allows Gilbert vehicles to preempt both the un-encoded TOMAR within Gilbert and encoded GTT intersections in adjacent jurisdictions.

Preemption Signal Phase

In terms of preemption signal phase, nine (42.8%) jurisdictions employed only green ball indications for both through movements of the preempted approach at both permissive and protected left turn locations. Eleven (52.3%) jurisdictions employed green ball indication and green arrow for the preempted approach at the protected left turn locations, and green ball indication for both through movements at the permissive left turn locations. City of Maricopa has deployed the EVP hardware but has not configured it for operation as yet.

Mesa originally deployed green ball and arrow at all protected left turn intersections. Efforts were made to convert all those intersections into green ball indication for both through movements. The conversion effort was halted per request from the Mesa Fire Department. This leaves half of the intersections with green indication only, and the other half with green indication and arrow. A resolution is being pursued with the Mesa Fire Department.

Additional surveys were conducted at the request of project stakeholders to identify the total number of intersections with green ball indications for both through movements of the preemption approach (Scenario “B”) and with green ball and green arrow for only the preemption approach (Scenario “B+A”), regardless of signal phasing. MAG member agencies were contacted to provide the breakdown of the number of intersections operating the different scenarios. Of the intersections in the region with EVP operations, 72% of intersections operate with Scenario “B” during preemption, and 28% of intersections with Scenario “B+A”.

Confirmation Light

The majority (59%) of responding jurisdictions did not deploy the confirmation light. This includes municipalities with a high level of EVP implementation, including Chandler, Gilbert, Mesa, Peoria, Scottsdale and Tempe. Five jurisdictions (22.7%) deployed 4-way confirmation lights, including Avondale, Paradise Valley (contracted to Phoenix), Phoenix, Tolleson and Pinal County. Three jurisdictions (13.6%) deployed 2-way strobe type confirmation lights, including Apache Junction, El Mirage and Surprise. In unincorporated areas, Maricopa County has implemented both types of confirmation lights based on the requirements of different fire districts. Although agencies are documented as having confirmation lights, not all signal locations within the particular agency have confirmation lights deployed.

Additional surveys were conducted at the request of project stakeholders to identify the total number of intersections with and without confirmation lights. MAG member agencies were contacted to provide the breakdown of the number of intersections with EVP operating with deployed confirmation lights. Of the intersections in the region with EVP operations, 5% of intersections operate with confirmation lights, and 95% of intersections do not have confirmation lights deployed.

Users of the EVP System

Fire departments are the primary users of the EVP systems. In most jurisdictions, ambulance service is also granted access to the EVP system. Police was initially excluded from using the EVP system citing the higher travel speed of the police cruiser than the fire engine (thus requiring a shorter response time to transition the traffic signal into preemption mode), and potentially more preemption calls due to higher police presence. Nonetheless, more jurisdictions are including police as EVP system users. Figure 8 shows the distribution of type of EVP system users in the MAG region.

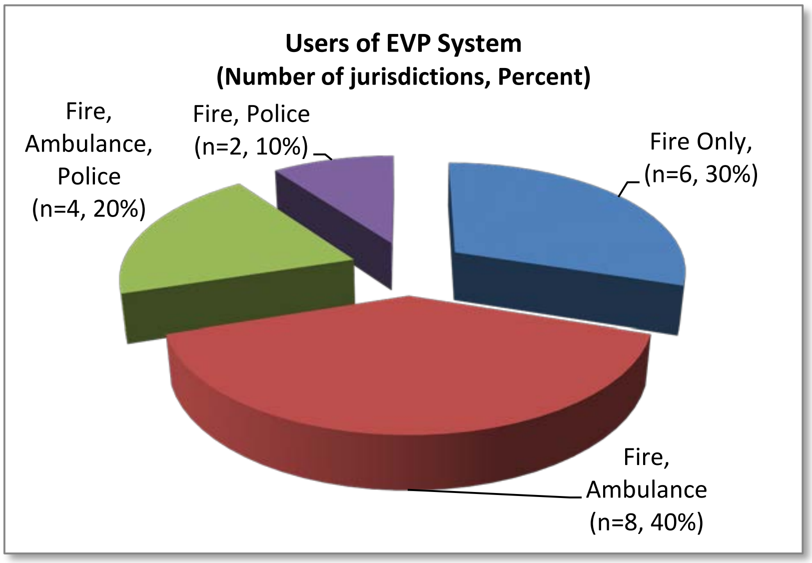


Figure 8. Users of EVP System

The City of Maricopa and Pinal County have only procured their roadside equipment and have not identified system users. The City of Surprise plans to include police in 12 months. The City of Mesa is conducting a test involving 12 police cruisers. The objective of the test is to understand the police usage patterns in support of future decisions. The City of Tempe has provided EVP access only to city-contracted ambulances, in addition to the Fire Department.

Maintenance

All jurisdictions provide maintenance in response to trouble calls typically requested by fire departments. The scope of maintenance typically includes diagnosing any hardware and wiring issues. Most jurisdictions included EVP as part of the annual or biannual traffic signal preventive maintenance. The preventive maintenance includes cleaning of the detector lens and testing preemption activation using the test button on the preemption detector card. Many jurisdictions include EVP inspection and testing as part of their regular traffic signal cabinet maintenance as frequently as every 2 to 6 months. Several jurisdictions also test the preemption system by driving with an emitter.

Review Usage Data

The preemption detector card keeps a log of preemption events which can be downloaded in the field using a laptop. The log provides useful information on time and day of the preemption event and, if encoded, the emitter ID that can be traced to an authorized vehicle or used to identify unauthorized preemption requests. Most jurisdictions reported that usage data is only downloaded in the field as needed in response to trouble calls.

Both GTT and TOMAR offer management software[21] that allows remote download of the usage data if communication is provided to the traffic signal cabinet. Mesa, Tempe and Peoria are active users of the GTT Central Management Software (CMS). The CMS can be used to update firmware, adjust preemption settings, download usage data (including emitter ID), and generate usage reports. Since upgrading their central traffic signal management system, Peoria has increasingly relied on the signal controller log in the traffic signal management software to analyze preemption events. Ideally both management systems would be integrated to preserve data integrity and fidelity.

The central traffic signal management system captures detailed start and stop times of a preemption event, as well as the transition time for a traffic signal to get back in sync with the adjacent intersection. Chandler, Glendale, Mesa, Peoria, Scottsdale and Tempe routinely utilize the central traffic signal management software for trouble shooting as well as assessing traffic impacts associated with the preemption events.

Transit Low Priority Application

Valley Metro began using the optical EVP system to provide low priority Traffic Signal Priority (TSP) to the LINK Bus Rapid Transit (BRT) services in the East Valley in 2013. The TSP is provided for two BRT routes: the Main Street route serves between the Sycamore light rail station in Mesa to the Park-and-Ride lot at the northwest corner of the US-60 and Power Road. The Country Club Road/Arizona Ave route serves between the Sycamore light rail station and Germann Road in Gilbert that spans across Mesa, Chandler and Gilbert.

At 40 of the EVP equipped intersections in Mesa and two intersections in Gilbert, the same equipment is configured to recognize BRT (Bus Rapid Transit) vehicles. The buses use a low-priority emitter that can be over-ridden by emergency vehicle preemption. The bus activates a request for service only if it is behind schedule. The intersection either advances or extends the

[21] Central Management Software (CMS) from GTT, OSPtrack from TOMAR.

green indication to facilitate the passing of the bus. Unlike preemption, the TSP does not typically require the traffic signal to transition to get back in sync with the adjacent signals. Using the encoded GTT system and the Central Management Software, Mesa is actively monitoring the usage of the TSP and provides feedback to Valley Metro regarding the performance of the TSP.

1.3 Operational Challenges

It was evident from the regional survey that the lack of standards and coordination in EVP implementation has resulted in inconsistent operation across the MAG region. As emergency vehicles increasingly operate outside of their jurisdictional boundaries in support of automatic aid agreements and mutual aid agreements, these inconsistent operating environments pose a challenge to both emergency responders and the general public alike. This section provides a discussion of these issues associated with varying EVP operations across the MAG region.

1.3.1 Incompatibility Between Systems

The first and foremost challenge of the EVP operation in the region is the compatibility between the encoded and un-encoded EVP systems. When an EVP system is encoded, it will only accept preemption requests from an encoded emitter with a valid ID code.

In response to several highly publicized incidents of abuse in early 1990, 3M developed an improved version of Opticom that can be encoded to prevent un-encoded road emitters from activating preemption. Starting in 1994, the City of Mesa was the first jurisdiction in the MAG region to encode their Opticom EVP system. In 2010, a working group involving several East Valley jurisdictions was formed to coordinate EVP operations, including:

- Coordinate EVP system encoding practices to ensure interoperability.
- Develop and maintain a code assignment scheme (based on the Opticom system) that can be used by all agencies in the region, including fire department, police, ambulance, transit, and other users. Each participating agency is assigned a unique block of ID codes.
- Coordinate the traffic signal phase provided during the preemption.

As of today, the East Valley EVP Working Group has expanded to include Cities and Towns of Apache Junction, Chandler, Gilbert, Guadalupe, Mesa, Queen Creek, Scottsdale, Sun Lakes and Tempe. The code assignment developed by the working group also includes placeholders for all emergency response agencies in the MAG region. Figure 9 shows the timeline of EVP encoding in the MAG region.

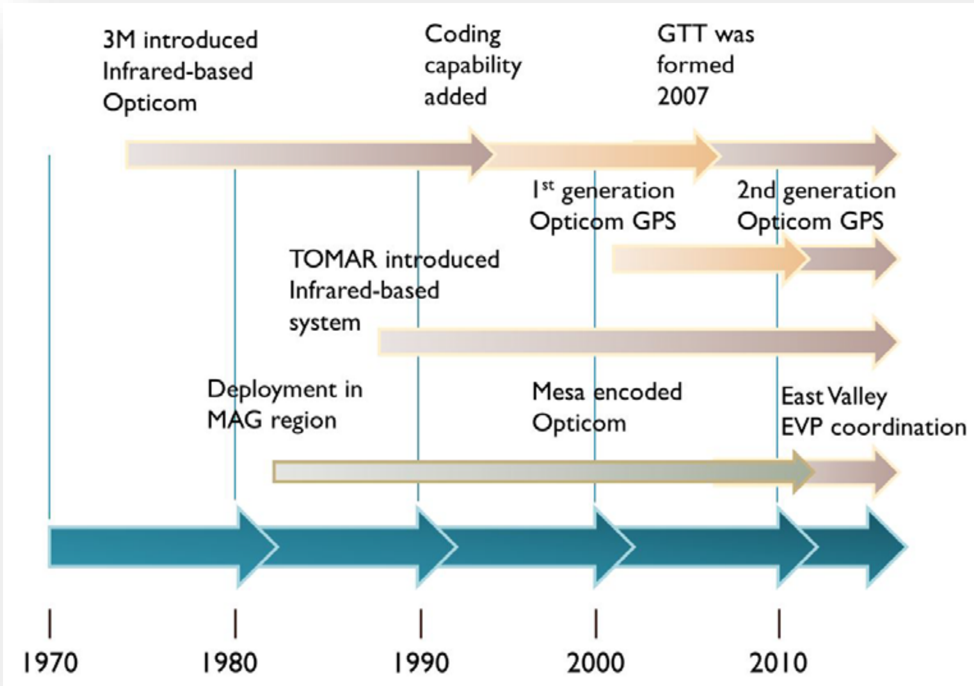


Figure 9. History of EVP Implementation in the MAG Region

As jurisdictions started encoding their EVP systems to improve security, it introduced incompatibility between the encoded and un-encoded systems. In general, an encoded vehicle emitter will be able to request preemption from an un-coded (open) roadside system. On the other hand, an un-encoded emitter will be locked out of the encoded field system.

Currently, six jurisdictions that encode their EVP systems account for a total of 865 intersections (45%). Un-encoded EVP systems (16 jurisdictions) account for a total of 1,055 intersections (55%) in the region. Table 2 illustrates the compatibility between the EVP systems based on their encoding status. The Y designation indicates that an equipped emergency vehicle from a jurisdiction in the left column is able to preempt the traffic signal in a jurisdiction in the top row. The N designation indicates incompatibility between two systems. The brand of the EVP system and the encoding status are provided for reference, where G stands for GTT, T stands for TOMAR, and the encoding status is provided in parenthesis. Gray colors indicate non-adjacent agencies, yellow colors indicate incompatibility between non-adjacent agencies, green colors indicate compatibility between adjacent agencies, and red colors indicate incompatibility between adjacent agencies.

Table 2. Compatibility between EVP Systems

	EVP Brand (Encoding Y/N)	Apache Junction	Avondale	Buckeye	Chandler	El Mirage	Fountain Hills	Gila River Indian C.	Gilbert	Glendale	Goodyear	Maricopa	Mesa	Paradise Valley	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson	Queen Creek	MCDOT	Pinal County
		G (Y)	T (N)	G (N)	G (Y)	G, T (N)	G (Y)	G, T (N)	T (N)	T (N)	G (Y)	N/A	G (Y)	T (N)	G (N)	T (N)	G (N)	T (N)	G (Y)	T (N)	T (N)	T (N)	G (N)
		Operating in the above jurisdictions																					
Emergency Vehicles from the jurisdictions on the left																							
Apache Junction	G (Y)		Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Avondale	T (N)	N		Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Buckeye	G (N)	N	Y		N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Chandler	G (Y)	Y	Y	Y		Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
El Mirage	G, T (N)	N	Y	Y	N		N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Fountain Hills	G (Y)	Y	Y	Y	Y	Y		Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gila River I C.	G, T (N)	N	Y	Y	N	Y	N		Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Gilbert	G[22] (Y)	Y	Y	Y	Y	Y	Y	Y		Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Glendale	T (N)	N	Y	Y	N	Y	N	Y	Y		N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Goodyear	G (Y)	Y	Y	Y	Y	Y	Y	Y	Y	Y		-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Maricopa	?	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Mesa	G (Y)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	-		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Paradise Valley	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N		Y	Y	Y	Y	N	Y	Y	Y	Y
Peoria	G (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y		Y	Y	Y	N	Y	Y	Y	Y
Phoenix	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y		Y	Y	N	Y	Y	Y	Y
Scottsdale	G (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y		Y	N	Y	Y	Y	Y
Surprise	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y		N	Y	Y	Y	Y
Tempe	G (Y)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
Tolleson	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N		Y	Y	Y
Queen Creek	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y		Y	Y
MCDOT	T (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y		Y
Pinal County	G (N)	N	Y	Y	N	Y	N	Y	Y	Y	N	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	

It should be noted that compatibility between agency EVP systems becomes an important consideration mostly for sharing resources related to emergency services amongst adjacent jurisdictions via aid agreements.

Since reverting to un-encoded systems may not be a practical option exercised by MAG member agencies, the ultimate resolution to the compatibility issue would be to encode all EVP systems in a compatible way. That is, all EVP systems will need to be able to transmit codes that are

[22] Gilbert deploys encoded GTT emitters that can preempt encoded GTT and un-encoded TOMAR intersections.

recognized by both competitive products in order to request preemption and track vehicle emitter ID. There are several hurdles that need to be overcome:

- Without sacrificing the commercial interest, the hardware manufactures need to agree upon a least common denominator to accept preemption requests from an encoded competitive emitter[23].
- The jurisdictions need to recognize the importance of encoding EVP systems. The expected benefits of an encoded system include:
    - Improved security (by locking out unauthorized rogue emitters).
    - Ability to monitor the users with unique IDs and identify unauthorized requests.
    - Improved troubleshooting capability by associating a vehicle unit with a particular preemption event.
    - Provision for managing current and future growth of the system users.
    - Provision for generating data for performance metrics.
- There will be costs associated with encoding all the EVP systems, provided that manufacturers come up with a solution to address the system compatibility. Based on the East Valley Working Group experience, the following costs may be incurred:
    - Upgrade old EVP components. Especially for early adopters, there are likely multiple generations of products deployed in the field. To employ modern features such as encoding, a systematic review needs to take place to determine the needed upgrades.
    - Deployment of additional or new central EVP systems.
    - Staffing in support of performance monitoring, maintenance coordination, upgrade and new implementation planning, and proactive management of the EVP system users.

1.3.2 Inconsistent Preemption Treatments

Inconsistent preemption treatments are evident throughout the MAG region in two aspects: (1) traffic signal phase provided during preemption and (2) the use of the confirmation light(s). These inconsistent treatments add uncertainties to the decision making of the emergency vehicle operators who may provide automatic or mutual aid in unfamiliar jurisdictions.

<u>Preemption Traffic Signal Phase</u>

[23] The latest version of TOMAR preemption detector card can accept the signal from an encoded GTT emitter. However, it will log the vehicle ID as "Competitively Coded". As technology patents are expiring/lapsing, this functionality is also changing to allow vehicle IDs.

As shown in Figure 10, there are at least two variants of the preemption traffic signal phase used in the MAG region. Scenario “B” (9 jurisdictions) provides green indication for both through movements at both protected left turn and permissive left turn locations. Scenario “B +A” (11 jurisdictions) provides green indication for both through and left turn movements of the preempted direction at the protected left turn intersections. At the permissive left turn locations, green indication is provided for both through movements coinciding with the preemption direction.

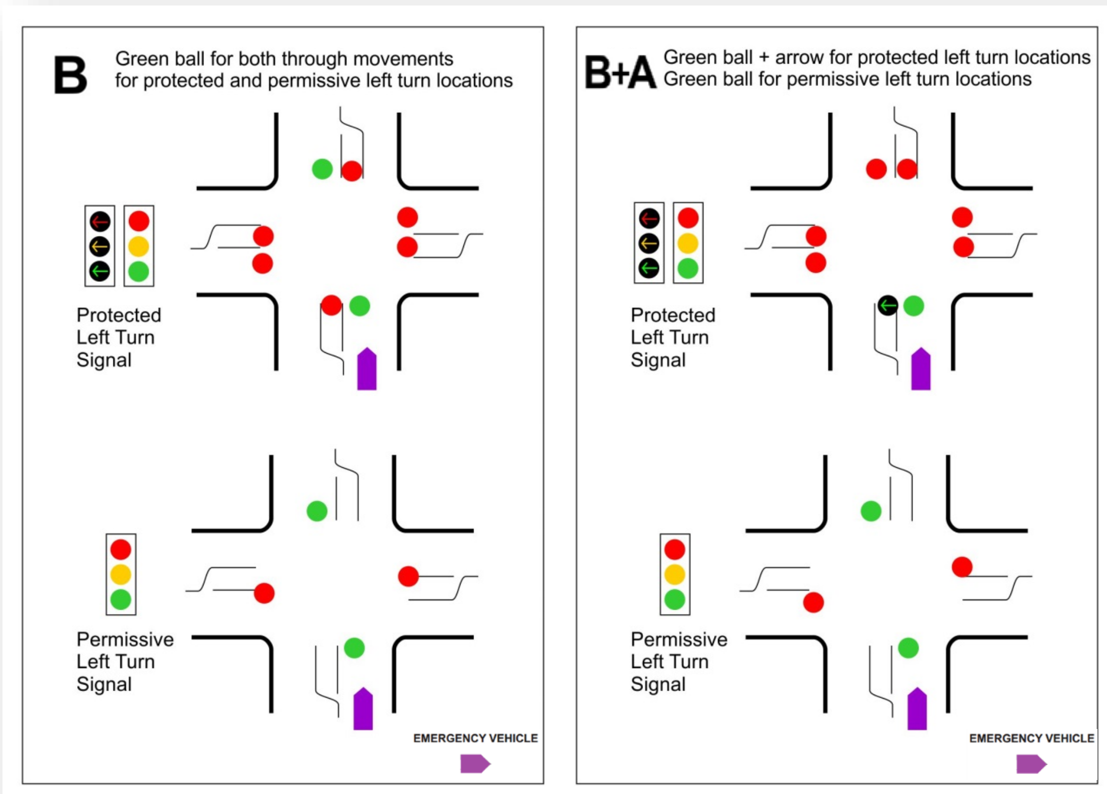


Figure 10. Alternative Preemption Signal Phases in MAG Region

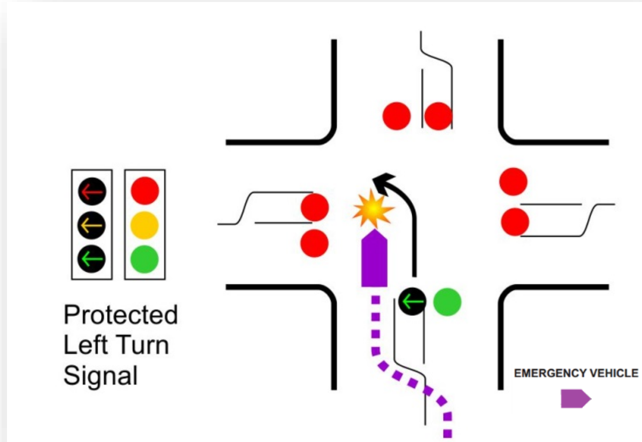


Figure 11: Plausible Collision Scenario Associated with Protected Left Turn Indication

Traffic engineers hold different opinions regarding the advantages and disadvantages of the two alternatives. The most stated safety concern of Scenario "B+A" is based upon the fact that fire engines are allowed to cross into the opposing traffic lanes. As illustrated in Figure 11, the behavior of the fire engine increases the likelihood of colliding with the unsuspecting left turning vehicles during the preemption. There are, however, no accident statistics to support the claim. The primary advantage of Scenario "B+A" (protected left turn) is the effective elimination of conflicting traffic from all non-preempted approaches and positive indication of the preemption direction. The major disadvantage is that there will be a yellow trap for protected-permitted signals unless the signal goes to an all-red condition, which further delays the beginning of the preempt dwell phases.

The common denominator between the two scenarios is the green indication for both through movements. This configuration makes up the largest share of signalized intersections in the MAG region. The major disadvantage of providing green through indication is the inability to differentiate the direction of the emergency vehicle because both opposing approaches display the same green indication. The ability to indicate the preemption direction provides a positive feedback to the emergency vehicle operator and the general public. Another benefit is that it matches perfectly with 2-strobe confirmation configuration.

It is not an easy task to settle the preference of different preemption treatments. For example, despite years of coordination and cooperation, the East Valley EVP Working Group was not in unanimous agreement regarding the preemption traffic signal phase. While the majority of the members agree upon the green indication for both through movements, the City of Gilbert has decided to retain the through and left indications for the protected left turn locations. The City of Mesa, which originally deployed the through and left indications for protected left turns, has started converting to the green indication for both through movements. Half way through the conversion, the effort was halted by a request from the Mesa Fire Department. As of January 2015 City of Mesa Transportation and Fire Departments came to an agreement on the operation of traffic signals during preemption. Scenario "B" is being used for permissive-only and protected-permissive displays. Scenario "B+A" is being used for protected only and flashing yellow arrow displays. The conversion to the agreed up standard is ongoing.

These lessons confirm the importance of having a regional coordination mechanism that is endorsed by the policy and decision makers of all relevant agencies when it comes to improving the regional consistency in EVP operations.

Confirmation Light

The confirmation light is not deployed by most of the larger jurisdictions, with the exception of the City of Phoenix. The confirmation light has found greater acceptance within smaller and newer jurisdictions.

However, the two variants of confirmation light deployed in the region are not functionally equivalent. The 4-way flood light[24] provides the following functions:

- There are four lights each aiming at an approach. During preemption, only one light is turned on (steady) to indicate the direction of the emergency vehicle's approach.
- In the case of multiple preemption requests, a flashing light indicates that the right-of-way is denied due to a competing preemption request from another approach.

The 2-way, 2-color strobe light provides the following functions:

- The blue strobe light indicates the preemption coming from the east-west directions.
- The white strobe light indicates the north-south direction.

The advantages of the 4-way flood light are (1) the positive confirmation of preemption direction and (2) the ability to handle the concurrent preemption requests. The benefit of the 2-way strobe light is that the strobe can be seen from all approaches and thus benefit not only the emergency vehicle but also the general public. The shortcoming of the 2-way strobe light is its inability to indicate the actual approach of an emergency vehicle. One of the concerns for confirmation lights in the visibility of light during daytime and under challenging lighting conditions. Another concern is that confirmation lights do not have a uniform meaning.

1.3.3 Management of EVP System

Usage Data

From a traffic management standpoint, EVP activation has a significant disruptive effect on traffic flow. Each time an intersection is preempted, it interrupts the normal cycling of the traffic signal. After the preemption, the signal phase transition may take several cycles for a traffic signal

[24] Referring to the incandescent flood light as the technology was initially deployed. While the casing remains similar in shape, high performance LED is now commonly used as the light source.

operation to get back to coordinated operation with the rest of the network. Based on an analysis conducted by the City of Mesa[25] using the traffic signal controller logs, each preemption event lasted an average of 34-35 seconds but the traffic signal could take between 1 minute 45 seconds and 2 minutes 28 seconds to get back in coordination. Additionally non-coordinated phases could theoretically have long delays before returning to normal operations.

As the utilization of the EVP system continues to increase, additional usage of the system should be carefully justified based on needs and potential impacts on the traffic network. It was evident in the regional survey that most jurisdictions did not fully utilize the system functions to support the traffic management objectives.

One such function is to conduct regular review of the usage data. The preemption detector card stores the detailed data of preemption events in the data buffer. These data are stored for up to a specified number of events before being overwritten in the buffer. The usage data can be downloaded in the field or using a direct laptop connection. If communication is available, central management software offered by the EVP manufacturer can be used to remotely download the data, eliminating the time-consuming task of field visits. An ancillary benefit of the central management software is to sync the clock in the preemption detector cards, which otherwise would probably not maintain accurate time stamps. For an encoded system, the usage data would contain individual emitter IDs for monitoring authorized and unauthorized requests.

Another source of the usage data is the traffic signal controller logs maintained by the central traffic signal management system. The advantage of traffic signal controller data is that it provides signal transition time after the preemption which is not available from the preemption detector card. The limitation of the signal controller log is that it does not contain the vehicle emitter ID associated with the preemption event and thus cannot be used for managing the users.

Staffing

The level of staffing involved with the EVP operation varies significantly across the region. For those cities relying on other jurisdictions to maintain traffic signals, the EVP operation is limited to reactive repair. In some cities, the EVP operation is delegated to the traffic signal technicians and maintained like other stand-alone traffic signal equipment. Usage data is examined for the sole purpose of troubleshooting.

For more engaged cities, the EVP operation is better coordinated between the traffic operation staff, traffic signal technicians and the Fire Department. The traffic operation staff would typically serve as the point of contact with the Fire Department regarding operational issues. For trouble calls, they can examine the usage data and perform preliminary diagnosis to determine

[25] Priority Treatment at Traffic Signal, A. Dock, August 27, 2013

the root cause, before delegating the repair to the traffic signal technicians. In at least one city, the traffic operation staff also works closely with the vehicle maintenance of the Fire Department to maintain the list of active users (vehicle emitter ID). This keeps the traffic department aware of any updates and changes to the users of the EVP system.

As a region, the experience of EVP operation needs to be better shared between the jurisdictions. This would reduce the learning curve and improve the regional coordination in EVP operations.

1.3.4 Maintenance of EVP in Large Jurisdictions

The maintenance of the EVP roadside system is carried out as part of the traffic signal maintenance. The activity typically involves inspecting wiring, testing the preemption detector cards, cleaning the optical detector, and driving the intersection with an emitter. For jurisdictions with relatively few signalized intersections, the maintenance is typically carried out every 2 to 6 months, according to the survey. For a large jurisdiction, conducting effective maintenance on the EVP becomes very challenging due to the sheer number of the intersections.

While it is relatively easy to aim an emitter at a detector to verify if the preemption is "working", a thorough testing on the EVP would require a two-person team with more work than a typical cabinet maintenance entails. One technician needs to be at the traffic signal cabinet where the preemption detector cards are housed. The other would need to position a test emitter (in a vehicle) at the intended detection distance so that the person at the traffic signal cabinet can verify the range (signal intensity level). Compared to traffic signal cabinet maintenance, this process is extremely labor intensive and stretches the maintenance resources. Other needed maintenance such as cleaning the optical detector lens on the mast arm is also laborious and traffic impeding.

Another methodology involves a vehicle equipped with GPS capacity to emit the preemption signal. The captured data includes the position, velocity, and time. The driver can engage the preemption for the signalized intersection from each direction. The central management software captures the preemption event data which can then be compared with the GPS data. This methodology was developed by Arthur J. Dock with the City of Mesa and documented in the white paper titled "Using GPS/GIS to Test Emergency Vehicle Traffic Signal Preemption". These maintenance requirements are uniquely associated with the optical-based detection system.

2. REVIEW OF CURRENT EVP TECHNOLOGIES

2.1 Optical-based EVP System

The optical-based EVP system is currently deployed in Arizona. The main components of an optical-based EVP system include: 1) Emitters that send the optical signal from the emergency vehicle to request the preemption; 2) Detectors (on traffic signal mast arm) that receive the signal and relay it to the traffic signal cabinet for processing; and 3) Preemption detector cards (housed in the traffic signal cabinet) that process the signal, determine its validity, log emitter ID, and initiate the preemption call to the traffic signal controller. The confirmation light that indicates the status of the preemption request is considered an optional feature of an optical-based EVP system.

The vendors that own the major market share of the optical–based EVP system in the MAG region are Global Traffic Technologies (GTT) and TOMAR Electronics. Other EVP products are available from EMTRAC, MIRT, and EViEWS, which are not currently deployed in Arizona. GTT is the successor to the original Opticom product invented by 3M in the 1970s. Opticom has been the de facto standard of optical-based EVP until when TOMAR electronics developed the STROBECOM EVP system.

GTT and TOMAR optical-based systems are interoperable, in terms of the ability to preempt an intersection, if they are not encoded (commonly referred to as open). However, when encoded, the GTT and TOMAR systems are not interoperable. Table 3 summarizes the advantages and disadvantages of encoding with respect to EVP operations.

Table 3. Comparison of Encoded and Un-encoded Systems

	Advantages	Disadvantages
Un-encoded Mode (open)	• Equipment from multiple vendors is interoperable in terms of being able to preempt an intersection • Easy to manage as vehicle emitter codes are not required to activate preemption	• Susceptible to illegal activation by rogue emitters • Susceptible to unauthorized activation by existing system users • Does not make full use of system functionality (ID logging, relative priority)
Encoded Mode	• Prevent activation by rogue emitters • Enable tracking of system usage by individual vehicles • Enable advanced features such as relative priority	• Lack of a national standard – different systems are not interoperable when encoded • Require central administration of vehicle codes for all regional agencies

After the expiration of the original (3M) Opticom patents in 2009, other manufacturers are now offering the generic parts (emitter, detector, phase selector) that can replace the GTT components. The generic components will allow the activation of the preemption, in Opticom mode, using a mixture of GTT and GTT-compatible products. The generic GTT field components, however, do not support the data communication features that allow the use of GTT's Central Management Software (CMS) for on-line system monitoring, configuration, and reporting of the system usage data.

Some incompatibility issues still exist between the GTT Opticom system (e.g., deployed by the East Valley EVP Working Group) and the native TOMAR STROBECOM system (e.g., deployed by City of Phoenix and 8 other jurisdictions). As technology patents expire and change, these issues are encountered when GTT systems received encoded vehicle IDs from different systems.

2.2 GPS/Radio-based System

GPS/radio-based EVP system was commercially introduced in the late 1990s and marketed as a successor to the widely deployed optical-based EVP system. The GPS/Radio-based system replaces the optical detection (i.e., infrared emitters on the vehicle and optical detectors on the traffic signal mast arm) with radio communications. The benefit of using radio for vehicle-to-intersection communication is the elimination of the line-of-sight requirements associated with the optical-based system. This greatly simplifies the installation and maintenance at the intersection by eliminating optical detectors (and cabling) on the mast arms.

The detection range determination, instead of using the light intensity level as the optical-based systems do, is based on the vehicle's distance to the intersection computed by using the vehicle's GPS coordinates. The evaluation of multiple concurrent preemption requests is based on the Estimated Time to Arrive (ETA) computed using the distance to the intersection (vehicle's GPS coordinates) and vehicle speed. This addresses a shortcoming of the simple, first-come-first-served arbitration employed by the optical-based system which cannot account for emergency vehicles approaching at different speeds. Table 4 compares the distinctive features between the GPS/Radio-based and optical-based EVP systems.

Table 4. GPS/radio-based and Optical-based EVP System Features Compared

	GPS/Radio-based EVP	Optical-based EVP
Preemption request medium	Radio wave	Infrared light
Line of sight	Does not require absolute line of sight	Requires absolute line of sight
Range setting	Activation is based on the ETA computed using vehicle position and speed from the GPS data. The inclusion of speed data accommodates different classes of vehicle moving at different speeds (e.g., fire, ambulance, and police).	Range is set at a fixed distance based on light intensity level. The lead time to preemption might be shorter for fast moving vehicles (e.g., police) as it takes less time to traverse the same distance.
Relative priority	Relative priority can be assigned to different classes of vehicle, including transit.	Feature is available when the system is encoded. Transit signal priority is treated differently using a dedicated low priority request[26].
Preemption confirmation	Onboard unit displays radio and preemption status using LEDs.	Must deploy confirmation lights at the intersection.
Preemption forwarding	Preemption requests can be automatically forwarded onto the next intersection.	Each EVP intersection is operating independently.
Usage tracking	Each radio has a unique MAC address in addition to the user assignable ID. Usage logs are available on phase selector and vehicle onboard unit.	Emitter ID is available when the system is encoded. Each emitter can be encoded with a uniquely assigned ID. However, the system cannot differentiate emitters encoded with duplicate IDs.
Field installation	Simplified installation. Only one radio unit is needed to strap to the traffic signal pole or mast arm. Traffic signal cabinet houses a phase selector that works with the radio unit.	Requires detectors on the mast arm for all approaches. Phase selectors are installed in the traffic signal cabinet.
Maintenance	No component on the signal mast arm requires regular maintenance.	Cleaning of detectors on the mast arm, verification of detection range (traffic impeding) is required.

[26] Emitter is configured to pulse at 14 Hz for the high-priority preemption request, or 10 Hz for the low-priority transit Traffic Signal Priority (TSP) request

Figure 12 illustrates vehicle components and intersection installation of the GPS/Radio-based EVP system (picture source: Global Traffic Technologies).

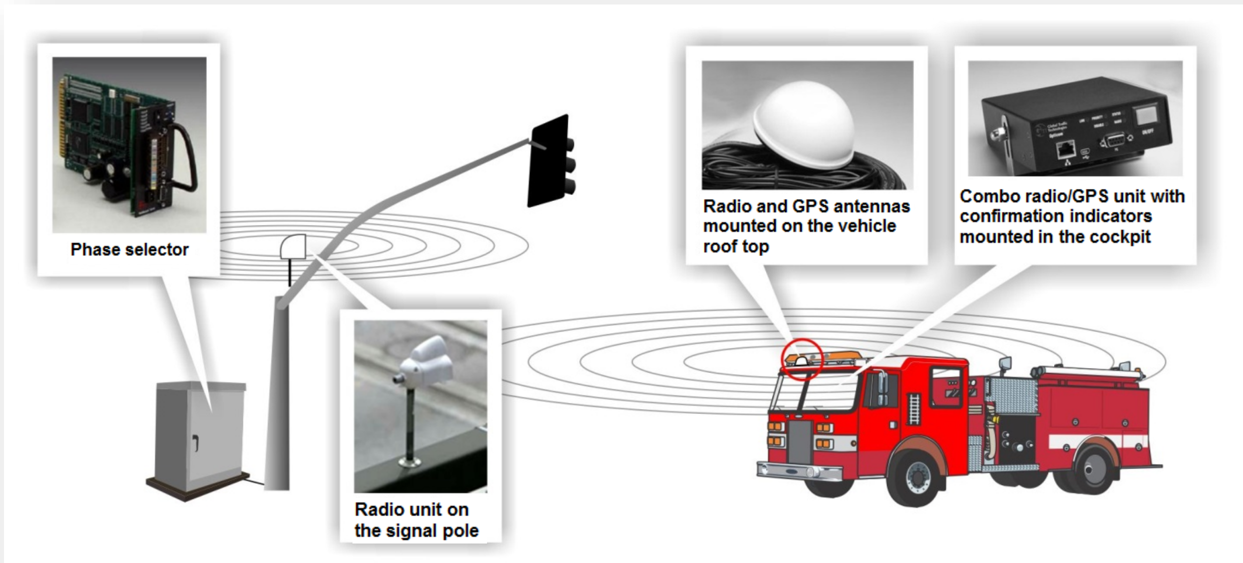


Figure 12. Components of the GPS/Radio-based EVP System

Vehicle Component

The vehicle component includes a radio, a GPS receiver, and a micro-processor with onboard memory. The GTT GPS-based system uses the Frequency-Division Multiple Access 2.4 GHz radio and EMTRAC and EViEWS systems use the 900 MHz radio. These radios are omnidirectional and the frequency-hopping feature automatically selects a channel without interference. GTT claims a nominal minimum range of 2,500 feet for its 2.4 GHz radio. EMTRAC indicated a range up to one mile for its 900 MHz radio due to the use of a lower operating frequency. The design approach for the vehicle component is different between vendors.

For GTT system, when a vehicle's transceiver (radio) is activated and comes within radio range of an equipped intersection, the vehicle transmits its location, heading, speed, turn-signal information and identification on a frequency channel, and time slot automatically assigned to it by the radio network. Intersections receiving this data compare the locations received (once per second) with a stored approach map to determine the approach and compute the ETA. The intersection then evaluates the concurrent preemption requests based on ETA and relative priority. GTT cited that the benefit of this design approach is that it does not require updating the intersection data on all the vehicle units since it is contained in the intersection equipment.

EMTRAC's vehicle component contains map coordinates of all the intersections in the network. The map data contain detection zones defined for each approach of all the intersections. The vehicle unit compares the current position and heading with the intersection map data to determine the requested preemption approach and compute the ETA. As a vehicle moves within the radio range of an intersection, the vehicle unit transmits the vehicle identification, relative priority, requested preemption approach, and ETA to the intersection. Intersections receiving this data will evaluate all concurrent preemption requests based on ETA and relative priority. EMTRAC can also push codes out through its "Interrogator System" which is typically deployed at the fire station or maintenance facility.

Both the GTT and EMTRAC onboard units include indicators for the radio and preemption status. It is important to note that both onboard units are compatible with the SAE J1708 data bus standard. This feature is especially valuable for transit applications where different devices can communicate with each other on the J1708 data network, including transit Automatic Vehicle Location (AVL) systems (providing schedule adherence), automatic passenger counters, fare box, and enunciator. For transit signal priority applications, the traffic signal priority will only be activated when the bus is loaded and behind schedule based on the integration of the AVL schedule adherence system and the automated passenger counter.

Intersection Component

At the intersection, one radio unit is mounted on the signal mast arm or strapped to the signal pole. A phase selector, housed in the traffic signal cabinet, works in conjunction with the data received from the radio. The phase selector evaluates the concurrent preemption requests based on ETA and relative priority and makes a preemption call to the traffic signal controller. This design, featured in GTT and EMTRAC's standard GPS-based products, is inherited from the optical-based system which also uses a phase selector for making preemption calls to the traffic signal controller. The major distinction is that the phase selector of the GPS/Radio-based system performs more computation and stores the intersection data (as in the case of GTT). These phase selectors are all equipped with communication ports that allow remote monitoring, data download, and configuration.

Hybrid Infrared and GPS System

To facilitate the migration from the optical-based system to the GPS/Radio-based system, major system vendors all provide a hybrid field system that can simultaneously work with a mixture of emergency vehicles equipped with an optical emitter or a GPS-based onboard unit. The hybrid phase selectors work with the input from the optical detectors on the mast as well as the radio unit. The benefit of a hybrid system is that it allows an agency to incrementally implement the GPS-based system while maintaining the compatibility with the legacy system.

2.3 Central/AVL-based System

The main appeal of a central/AVL-based EVP system is that there is no instrumentation needed in the field (e.g., preemption detector, phase selector). "Central" means commanding signal preemption from the central traffic signal management system, as opposed to relying on local detection that requires instrumenting each intersection with EVP equipment. Automatic Vehicle Location (AVL) means reporting the real-time location information of the emergency vehicle using GPS and wireless data communication to a central system. When an emergency vehicle receives a call from the 9-1-1 dispatcher, a preemption request is sent wirelessly from the vehicle to the central system along with the vehicle class, relative priority, and vehicle location, heading and speed from the GPS. The central system uses the continuously updated vehicle coordinates to determine the intersection on the approach and sends commands to the intersection to preempt the traffic signal.

The central/AVL-based traffic signal preemption/priority systems have only been deployed in a handful of implementations in the United States. Most of the deployed systems are exclusively for transit Traffic Signal Priority (TSP)[27] and very few are for Emergency Vehicle Preemption (EVP)[28]. The central/AVL-based system includes two major components, namely, an Automatic Vehicle Location (AVL) unit installed on the emergency vehicles, and the central system that processes the vehicle location data, initiates a preemption request, and (through the centralized traffic signal management system) preempts the intersection. Figure 13 illustrates the high-level functions of the central/AVL-based EVP system.

[27] Examples of the central/AVL-based Transit Signal Priority (TSP) include Manhattan, New York M15 corridor and Austin, Texas.
[28] Examples of the central/AVL-based Emergency Vehicle Preemption (EVP) include Miami, Florida and Windsor, Ontario.

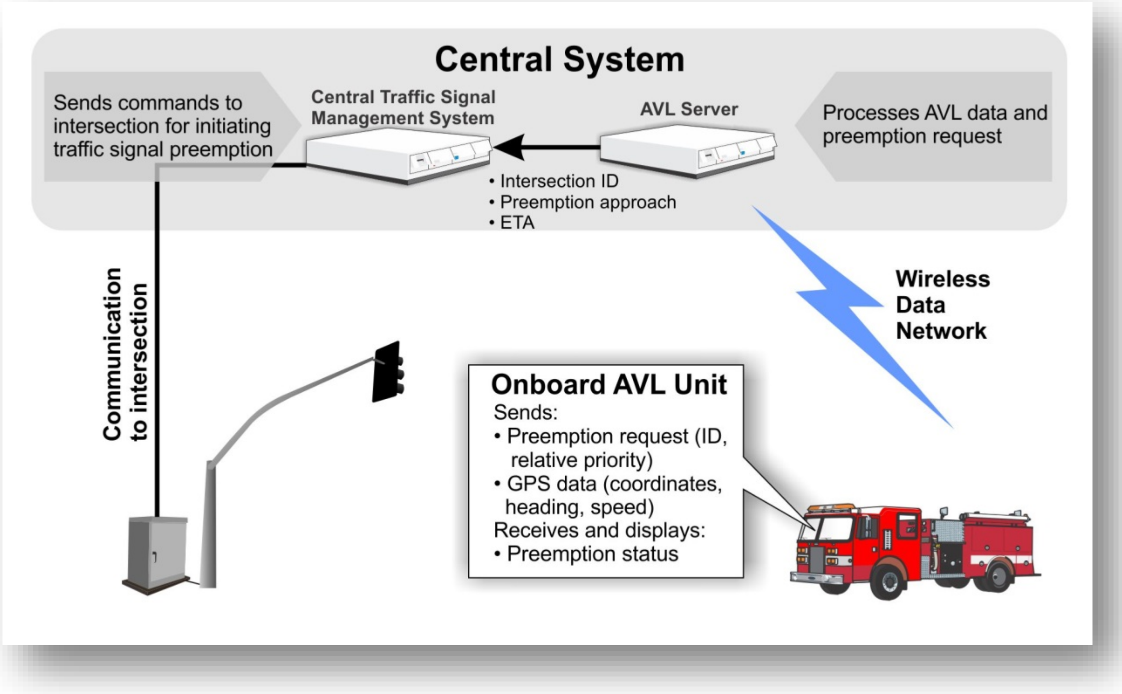


Figure 13. High-Level Functions of the Central/AVL-based EVP System

<u>**Automatic Vehicle Location (AVL) Unit**</u>

The emergency vehicles are equipped with an AVL unit which reports the real-time vehicle GPS coordinates to a computer server via a wireless data communication network (e.g., cellular 3G, 4G/LTE, public agency owned voice/data radio network). The onboard AVL unit can be integrated with the siren or a manual preemption switch. When the vehicle starts an emergency response, a preemption request is sent to the AVL unit and forwarded over the wireless data network to the central system. The preemption/priority request sent from the AVL unit typically includes:

- Unique radio ID
- Vehicle ID
- Vehicle class (emergency vehicle, transit, etc.)
- Relative priority
- Vehicle coordinates (latitude, longitude)
- Heading
- Speed

The central system can send updates back to the AVL unit to inform the emergency operator regarding the status of the preemption/priority request. In the case of transit priority, the AVL unit can be integrated with the Automatic Passenger Counter (APC) and schedule adherence system. Therefore, the signal priority request is only sent when the bus is loaded and/or behind schedule.

Central System

The central system performs the following functions:

- Receives preemption/priority requests and vehicle position updates from the AVL;
- Processes the vehicle coordinates and heading to identify the intersection and direction of preemption;
- In the case of multiple requests to the same intersection, determines the preempted approach based on relative priority and estimated time of arrival of the respective vehicles;
- Sends status of preemption back to the vehicle via AVL;
- Preempts the intersection from the central traffic signal management system.

With regard to preempting the intersection, two methods are commonly deployed.

1. **Dispatcher requests** [29]– This method requires defining the frequently traversed emergency routes in the system. When a preemption call is received, the dispatcher, based on the vehicle's location, manually initiates the preemption of all intersections, in sequence, along the defined route based on the estimated time of arrival. This application has been used for providing access from the fire house to the main roads.
2. **GPS algorithm requests** [30]- the central system processes the vehicle coordinates and heading to determine the approach and distance to the intersection. Speed information is used to refine the estimated time of arrival of a vehicle. As the current distance and ETA meet the pre-defined thresholds, a preemption request for that interstation is issued to the central traffic signal management system which, in turn, sends the commands to the intersection to initiate the preemption.

The advantages of the central/AVL-based system include:

- Does not require the installation of the preemption detection hardware at each intersection.
- No field maintenance requirements (major advantage over optical and GPS/radio-based systems).

[29] Implemented in Miami, Florida, and Windsor, Ontario using KITS
[30] Implemented in Austin, Texas using KITS, and M-15 corridor in Manhattan, New York using TransSuite

- When initiated by a dispatcher, preemption of all intersections in sequence can provide efficient progression for the emergency vehicle.
- Preemption activation based on vehicle GPS data is more accurate than the optical-based system which is based on the infrared light intensity.
- Multiple concurrent preemption requests may be addressed by the central system.
- Confirmation of preemption status is provided to the onboard AVL unit.
- Changing system parameters (e.g., activation criteria, AVL configuration) can be done from the central system over the data communications network.

The major disadvantage of the central/AVL-based system is its dependency on the communications system. Different from the optical and GPS/radio-based systems where preemption requests are processed locally at the intersection, the central/AVL-based system requires reliable communications for the AVL component and the centralized traffic signal operation. A system-wide network problem can effectively cripple all traffic signal preemption and priority functions. Despite this reliability a central/AVL-based system can work at 100% of the locations that have communications. Modern systems typically have evolving communications and connectivity is good. If an agency has a high level of communications to its signalized intersections, this established connectivity would provide the system users with the current level of functionality. The dependency upon an agency's communication capabilities is a trade-off with identifying reliability of the system.

2.4 Connected Vehicle EVP Applications

The Connected Vehicle Program is a federally sponsored research and development initiative by the USDOT that utilizes 5.9 GHz frequency Dedicated Short Range Communication (DSRC) to enable Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications.

The Connected Vehicle system consists of the following[31]:

- Applications that provide functionality to realize safety, mobility, and environmental benefits;
- Communications that facilitate data exchange;
- Core system that provides the functionality needed to enable data exchange between and among mobile and fixed transportation users.

Applications developed based on the Connected Vehicle technology provide connectivity:

- Among vehicles to enable crash prevention;
- Between vehicles and infrastructure to enable safety, mobility, and environmental benefits;
- Among vehicles, infrastructure, and wireless devices to provide continuous real-time connectivity to all system users.

According to a U.S. Department of Transportation (DOT) report, combined Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) systems could potentially address about 81 percent of all vehicle target crashes; 83 percent of all light-vehicle target crashes; and 72 percent of all heavy-truck target crashes annually.

With funding support from the USDOT, Arizona's Connected Vehicle program, led by the Maricopa County Department of Transportation (MCDOT), in association with the Arizona Department of Transportation (ADOT) and University of Arizona, is conducting research and development on an advanced multi-modal traffic signal priority control system that would one day lead to improvements in intersection operations involving multiple priority vehicles (e.g., fire, ambulance, police, and transit).

In 2007, the Arizona Connected Vehicle team successfully demonstrated the concept of priority ramp metering control for emergency vehicle operations using the Connected Vehicle technology. The initial research laid a foundation for the current development of the multi-modal traffic signal priority control, including emergency vehicle preemption. In 2012, Arizona successfully demonstrated multi-modal traffic signal priority control functionalities at the dedicated

[31] http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm

Connected Vehicle test bed in Anthem, Arizona. Intersections along Daisy Mountain Drive were instrumented with a Road Side Unit (RSU[32]) consisting of a DSRC radio communicating with the traffic signal controller[33]. Test emergency vehicles were equipped with an Onboard Unit (OBU[34]) consisting of a DSRC radio programmed with the priority request logic. Figure 14 shows pictures of the Anthem Connected Vehicle Test Site, Roadside Unit, Signal Controller, and Onboard Unit.

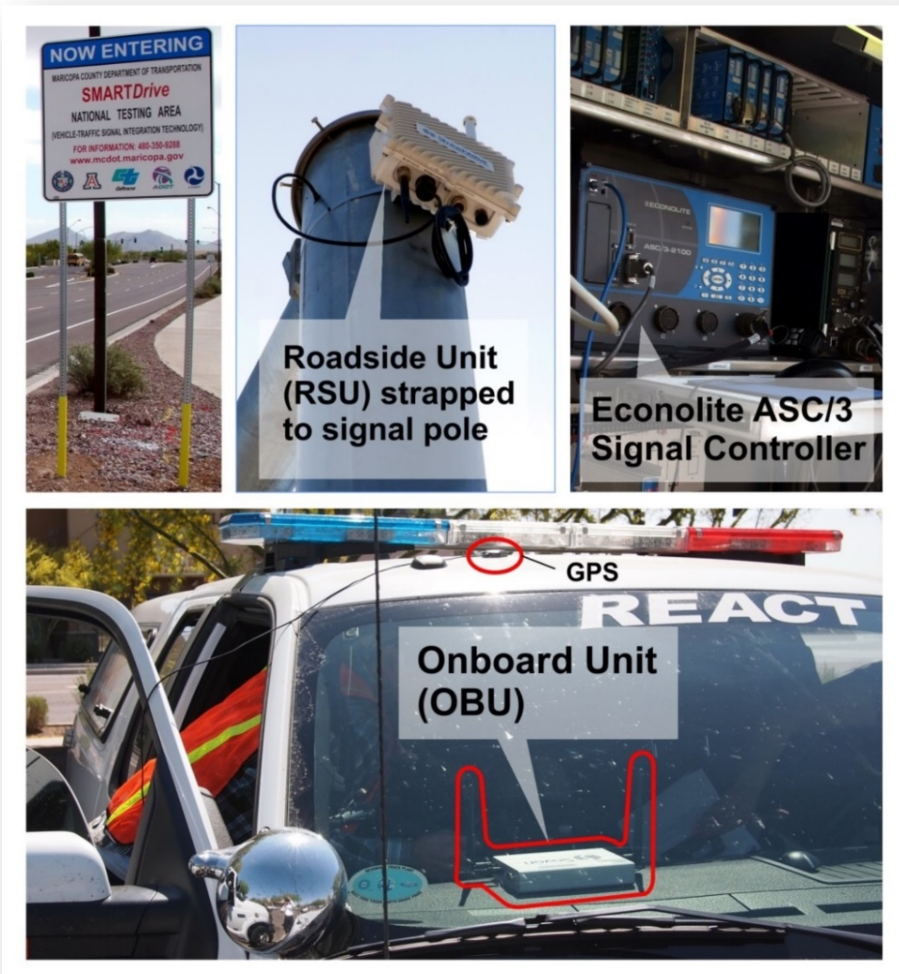


Figure 14. Pictures of Arizona Connected Vehicle Test Site and Equipment

[32] The Roadside Unit (RSU) consists of a Savari 5.9 GHz DSRC radio with applications providing communications with the equipped emergency vehicles and also sending commands to the traffic signal controller for priority treatment.
[33] Econolite ASC/3 controller is used in the Arizona Connected Vehicle test bed.
[34] The Onboard Unit (OBU) consists of the Savari 5.9 GHz DSRC radio with a microprocessor which can execute customized applications (e.g., vehicle priority).

Figure 15 illustrates elements of the Arizona Connected Vehicle traffic signal priority application.

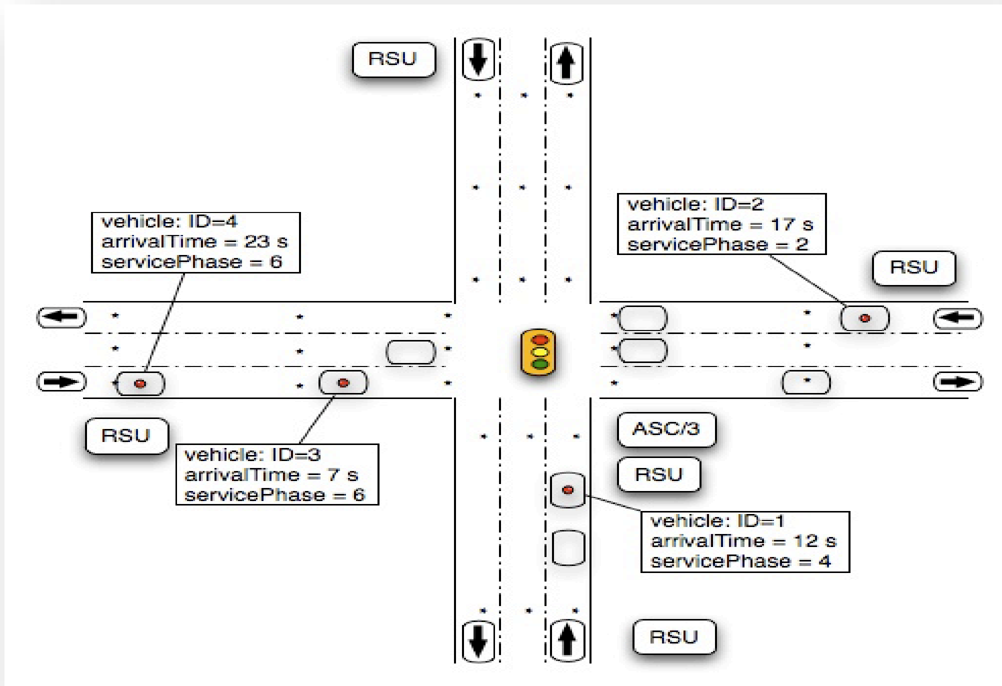


Figure 15. Elements of the Arizona Connected Vehicle Signal Priority Application[35]

The Arizona multi-modal traffic signal priority application has demonstrated the following functions:

- The Roadside Unit (RSU) at the intersection can engage with multiple emergency vehicles equipped with an Onboard Unit (OBU) as the vehicles move within the range[36] of the DSRC radio;
- Upon engagement, the OBU receives a map[37] broadcasted by the RSU which contains the layout of the intersections and traffic signal phase assignment information;
- The OBU on the vehicle plugs its current position on the map to compute the ETA and the requested signal phases. The request for priority is then sent from the OBU to the RSU at the intersection;

[35] Source: Dr. Larry Head, Department of Systems and Industrial Engineering, University of Arizona.
[36] Typical range of a DSRC radio is approximately 1,000 meters (3,280 feet). Although a direct line of sight is not needed, the actual range can be affected by tree canopies, building, terrain, and atmospheric conditions.
[37] SAE and FHWA message formats for Signal Phase and Timing (SPaT) and Map.

- The RSU evaluates all concurrent priority/preemption requests to determine the best signal timing strategy and sends commands to the traffic signal controller using NTCIP messages;
- When the equipped vehicle clears the intersection, it sends a message to the RSU and the signal returns to normal operation or serving other priority/preemption requests.

The similarities between the current commercially available GPS/Radio-based EVP and the Arizona Connected Vehicle signal priority application include:

- Use GPS to determine vehicle position
- Use a data radio for requesting signal preemption/priority
- Two-way communications between the road side and vehicle units
- Address multiple vehicle classes including transit

Nonetheless, the implementation approach for achieving the signal priority/preemption functionalities is largely discrepant from one another. Table 5 compares the Arizona Connected Vehicle application with current GPS/Radio-based EVP systems. It is important to note that both Arizona Connected Vehicle research and the cited commercial products are continuously evolving as the state of technology advances. The features compared in Table 5 reflect the state of development of all parties as of this report. There exist connectivity limitations and operations issues with the different radios. Propagation with 900 MHz radios is acceptable, but deteriorates with 2.4GHz and DSRC radios. There are concerns with how well DSRC radios will perform under the required distance when used as the critical link between a vehicle and a distant intersection.

Table 5. Comparison of Arizona Application with Commercially Available EVP Products

	Arizona Multi-Modal Traffic Signal Priority Application	GTT 2.4 GHz/GPS and Optical Hybrid EVP	EMTRAC 900 MHz/GPS and Optical–EVP/TSP
Communications	DSRC radio using SAE J2735 Message Set	2.4 GHz radio (standard product) DSRC radio (available as an option)	900 MHz radio (standard product) DSRC radio 5.9 GHz (available as an option)
Onboard Unit (OBU)	• Receive map data • Use GPS data (time point) to compute ETA • Use map and vehicle coordinates to determine ingress and egress (if known) • Send priority request (ID, vehicle type and class (priority level), ingress and egress (if known), ETA) to RSU	• Send request to intersection (GPS vehicle coordinates, heading, vehicle ID, vehicle class, agency, priority level, unique transit ID, transit ridership, turn indicator status[38]) • Use dead reckoning in case of loss of GPS as an option • Receive preemption status • Display radio status, and preemption status using LEDs • J1708/CAN vehicle data bus interface	• Contain a database of user-defined intersection approach detection zones • Use dead reckoning (gyros, wheel sensor, electronic compass) in case of loss of GPS signal • Compute ETA • Send preemption request to intersection (vehicle ID, relative priority, ETA, heading) • Check-in and check-out to turn request on and off • Send real-time vehicle location for AVL application
Roadside Unit (RSU)	• Broadcast map data to OBU • Receive priority request • Evaluate concurrent requests • Determine best signal timing strategy • Send commands to traffic signal controller using NTCIP • No phase selector or preemption card is used	• Phase selector containing a map of allowed approach corridors associated with the intersection • Receive preemption, TSP or probe priority request • Compute ETAs for all requesting vehicles within range • Evaluate multiple requests based on ETA, relative priority • Send preemption input from phase selector to controller (serial) or commands to traffic signal controller using NTCIP via Ethernet	• Preemption card to receive preemption request • Prioritize requests • Provide preemption input to traffic signal controller regarding direction of request • Optionally, send commands to traffic signal controller using NTCIP • Send received real-time AVL data and log to central computer via network connection
Priority logic	Employ optimization model to determine priority treatments considering ETA, queuing, and multiple relative priority	First-come-first-served based on ETA and relative priority	First-come-first-served based on ETA and relative priority.
Confirmation	Provide confirmation to vehicle regarding preemption status using SAE J2735 SSM (modified) message (proposed)	In-vehicle Preemption confirmation and radio status provided via LEDs on the onboard device. Intersection confirmation light available as an option.	Preemption confirmation provided on the onboard unit display.
Availability	Research and development	Optical systems have been available since the 1970s. 2.4 GHz version has been available since the early 2000s. DSRC radio can be used as an option.	900 MHz version is commercially available. DSRC available as an option or as a dual radio option.

[38] Turn indicator is used to forward a preemption request to the next intersection that the emergency vehicle is turning onto.

Compared to the current GPS/Radio-based products, Arizona Connected Vehicle application has the following differentiating characteristics.

- Use DSRC radio with SAE J2735 Message Set which ensures compatibility with other Connected Vehicle applications;
- Employs sophisticated optimization model to determine signal priority strategy, as opposed to ETA-based first-come-first-served logic;
- Send preemption calls directly from the RSU to the traffic signal controller (via Ethernet connection) without relying on preemption detector cards to make preemption calls to the traffic signal controller (this is a legacy design inherited from the optical-based EVP system).

Although the Arizona application is still many years from field deployment, the ground-up design and full compatibility with other Connected Vehicle applications have made it a development of significance to watch for. The Arizona Connected Vehicle research has been included as part of the national pooled fund study consisting of eleven members (states and local agencies). The focus of the pooled fund study includes:

- Developing strategies and path for Connected Vehicle infrastructure deployment;
- Equipment certification program;
- Multi-modal intelligent traffic signal system (FHWA Dynamic Mobility Application DMA designation)
    - Intelligent Traffic Signal System (ISIG);
    - Transit Signal Priority (TSP);
    - Mobile accessible pedestrian signal system (PED-SIG);
    - Emergency Vehicle Preemption (PREEMPT);
    - Freight Signal Priority (FSP);
- Commercial vehicle applications (future).

The framework and algorithms developed by the Arizona Connected Vehicle project would eventually benefit future emergency vehicle preemption applications as the industry moves toward the Connected Vehicle environment.

There is a concern with the existing EVP marketplace. Competing companies have multiple patents for using GPS navigation for preemption. Numerous instances of court cases indicate that patent infringement is still a concern with available technology. This develop is currently on-going.

3. STATE OF THE PRACTICE CASE STUDIES

The topic of state of the practice case studies focuses on the following issues and challenges concerning EVP operations in the MAG region as deployed in peer regions nationwide:

- **System Compatibility** - Regional efforts in addressing system compatibility across jurisdictions.
  - Chittenden County Metropolitan Planning Organization, Vermont
  - FAST, Nevada
  - Harris County, Texas
- **System Management** – Proactive use of EVP data for troubleshooting and usage monitoring
  - East Valley EVP Working Group of the greater Phoenix area
- **Preemption Treatment** – Coordination on the preemption traffic signal phase and use of confirmation light with the optical-based EVP system
  - State of Minnesota

3.1 Regional EVP System Compatibility

Regional system compatibility concerns the ability of an emergency vehicle to request traffic signal preemption in a neighboring jurisdiction that also deploys an EVP system. This need is increasingly important as agencies supporting regional emergency response automatic or mutual aid agreements routinely dispatch emergency vehicles beyond their home jurisdictions.

3.1.1 Case Study: Chittenden County Metropolitan Planning Organization, Vermont

Synopsis:

Led by the Chittenden County Metropolitan Planning Organization (CCMPO), an evaluation of regional traffic signal preemption/priority standards and practices was conducted in 2006. The study identified the two different optical-based EVP systems deployed in the region and made recommendations to encode the EVP system and migrate to a single compatible technology platform. The best practices described here include the planning process that developed a detailed plan for migrating to a secured and unified regional EVP system.

Description of Practices:

The EVP operations in the Chittenden County area were initially reviewed in a workshop when the region developed the ITS architecture and strategic plan in 2004. A second EVP workshop was held in 2006 as part of the project to evaluate the regional signal preemption/priority standard. The purpose of the second workshop was to develop a regional consensus approach to the future use of traffic signal preemption/priority technology in Chittenden County. The outcome of the workshop was a regional consensus and detailed approaches to develop an encoded EVP system based on a single technology platform.

The motivations for CCMPO to evaluate the regional preemption practices are:

- Concern about possible misuse of "un-encoded" signal preemption infrastructure.
- Underutilization of available signal preemption/priority features (e.g., encoding features).
- Potential dual use of the EVP infrastructure from the pending implementation of transit signal priority in the County.
- Deployment of traffic signal preemption technologies elsewhere in Vermont that could further complicate the regional inconsistencies, if not coordinated.
- Long-term impact of short-term, project-driven EVP procurement decisions due to lack of regional guidelines.

The 2006 EVP evaluation workshop effectively accomplished the following:

1. Reviewed the current utilization and practices of EVP in Chittenden County;
2. Reviewed the pros and cons of the (existing) un-encoded versus encoded EVP systems;
3. Reviewed, discussed, and voted on three possible options regarding the future regional EVP practices;
4. Developed recommendations for actions.

Each of the above steps is summarized in the following.

Current Utilization and Practices in Chittenden County

- Equipment from two major vendors, 3M/GTT (Opticom) and TOMAR (STROBECOM) are utilized in mixed proportions in various municipalities in the region, with the majority of installations using TOMAR technology.
- The signal preemption equipment in Chittenden County is operated in an un-encoded mode, whereby the emitters and field detectors utilize the industry standard of a 14MHz frequency for emergency signal preemption and 10MHz for transit signal

priority. This open standard, used by both 3M/GTT and TOMAR, provides interoperability between equipment provided by the two vendors.

- The signal preemption inventory in the County is in a state of constant evolution. The determination of which EVP technology to deploy is often left to the project contractor. If competed on a price basis, TOMAR has historically proven to be the lower cost option, and therefore is the technology most often deployed.
- The Chittenden County Transportation Authority (CCTA) was in the midst of planning for Transit Signal Priority (TSP) which could potentially share the EVP infrastructure.
- The Fletcher-Allen Health Care Medical Center Campus in Burlington is a major medical and trauma center serving a large portion of northern Vermont beyond the boundaries of Chittenden County. The EMS responders from rural communities currently benefit from an un-encoded signal preemption system when they travel to the medical center.

Comparison of Un-encoded and Encoded EVP Systems

- **Un-encoded Systems:** Un-encoded systems provide signal preemption to any vehicle emitting an optical signal at the correct frequency. This is a de facto standard within the industry that allows interoperability of un-encoded equipment from multiple manufacturers. Because un-encoded systems use a relatively simple technology, such systems are susceptible to unauthorized use.
- **Encoded Systems:** An encoded system is capable of logging the vehicle class code and unique vehicle ID that are useful for troubleshooting and managing usage. Encoding also prevents unauthorized use of the system by requiring confirmation of a special encrypted code in order to activate preemption functions. The drawbacks of moving toward an encoded system are:
  - Lack of a national "open" standard – region must choose one equipment manufacture's proprietary standard.
  - Require central administration of vehicle emitter ID codes when multiple agencies are involved.
  - Current capability for emergency responders traveling to the County medical facilities from other jurisdictions might be interrupted by the required encoding.

Comparison of Available Options

Three options regarding future EVP practices were developed for review by the regional partners.

Option #1: Stay un-encoded: The benefits are that all equipment will remain interoperable and there is no immediate investment aside from routine hardware replacement or system expansion.

Option #2: Gradual migration toward an encoded preemption standard: Upon adopting a preferred standard, the County would gradually move toward an encoded system by upgrading non-compliant or obsolete field and onboard equipment as it reaches the end of its service life. There is no cost to this approach since all new equipment purchased can operate in an encoded mode. It was estimated that an encoded system can be achieved with this approach within 5 to 10 years. The major drawbacks of this approach are the inability of un-encoded vehicle emitters to preempt an encoded intersection during the long migration period.

Option #3: One-time implementation of an encoded preemption standard: Upon adopting a preferred standard, the County would implement an encoded system through a one-time replacement of non-compliant or obsolete field and onboard equipment. The stakeholder would immediately realize the benefits of an encoded system. However, this is the largest up-front cost option to accomplish the switchover, and some onboard and cabinet equipment would need to be replaced before the end of its useful life.

After extensive discussion of the three options, the stakeholders voted to recommend Option #2: Gradual migration toward an encoded preemption standard.

Recommendations for Actions

The recommendations for implementing a regional encoded EVP system contain the following components.

- Recommendation #1: Selection of Encoded Technological Standard
- Recommendation #2: Near-term Technology Recommendations
- Recommendation #3: Requirements for Implementation of Encoded Operation
- Recommendation #4: Phasing in an Encoded Regional Standard
- Recommendation #5: Roles and Responsibilities
- Recommendation #6: Institutional Agreements

Recommendation #1: Selection of Encoded Technological Standard

Given the decision to migrate toward an encoded system, recommendation #1 provided a check list of items to be considered in selecting a vendor system, including:

- Factors in selecting a preferred technology
  - Suitability of technology to future needs
  - Transit requirements
  - Equipment condition and life cycle cost
  - Local technical support
- Information needed to support decision-making
  - A detailed articulation of the requirements of all potential system users

  - Identification of the quantity and location of existing and planned traffic signal preemption projects
  - Transit functional requirements and deployment details
  - A detailed equipment inventory of existing preemption and traffic controller hardware in the field.
- Procurement and cost competitiveness considerations
  - Cost of all roadside and in-vehicle components
  - Cost of replacement parts, including multi-year price guarantee
  - Maintenance agreement and warranty
  - Manufacture's incentives (e.g., trade-in credits)
  - Opportunities for joint procurement or negotiated price agreements through a regional entity.

Recommendation #2: Near-term Technology Recommendations

Based on the criteria described in recommendation #1, the region selected TOMAR STROBECOM II as the standard for the future encoded EVP system. Specific models of TOMAR discriminator (i.e., detection card), detector, and vehicle emitter were recommended for any near-term EVP implementation.

Recommendation #3: Requirements for implementation of Encoded Operation

Three prerequisites were identified for the transition to a regional encoded system:

- Conversion of all roadside equipment to the selected encoded standard
- Upgrading and programming of all vehicle emitters to be capable of transmitting an encoded signal to the encoded roadside equipment.
- Development of institutional agreements in support of system configuration and maintenance, including:
  - Procurement of new equipment
  - Initial system configuration and testing
  - Development of the regional coding scheme
  - System maintenance and troubleshooting
  - Collection and archiving of system use data log files

Recommendation #4: Phasing in an Encoded Regional Standard

- Phase 1: Implementation of near-term standard

- Phase 2: Develop technical specification and standardize future deployment of encoded equipment
- Phase 3: Deploy encoded transit signal priority (while EVP remains un-encoded)
- Phase 4: Define switchover schedule to encode the emergency vehicle preemption system

Recommendation #5: Roles and Responsibilities

The key point in this recommendation is to designate a lead implementation agency, other than the Chittenden County Metropolitan Planning Organization (CCMPO), whose role is to serve as regional facilitator. To transition from planning toward engineering design, implementation, day-to-day operations, and maintenance, it is desirable to involve one or more traffic signal operating agencies as a lead agency for the implementation of the regional encoded system. It was recommended that the Vermont Agency of Transportation (VTrans) lead the deployment of traffic signal preemption, and that the Chittenden County Transportation Authority (CCTA) lead the traffic signal priority deployment.

Recommendation #6: Institutional Agreements

This recommendation outlines the necessary institutional agreements in support of implementing the regional encoded system, including:

- Garnish endorsement of the regional consensus from regional decision-makers. An example of such endorsement is the Policy Statement signed by the CCMPO Board of Directors to endorse the gradual migration to the regional encoded EVP system based on the technology developed by TOMAR (Appendix A).
- Development of Interagency Agreements (IGAs) and or Memorandum of Understanding to memorialize the agreed upon technical standard, technology, configuration, operating procedure, and funding decision.

3.1.2 Case Study: FAST, Nevada

Synopsis:

The Freeway and Arterial System of Transportation (FAST) is an integrated Intelligent Transportation System (ITS) in the region that encompasses the greater Las Vegas metropolitan area. In 2009, under the leadership of the Regional Transportation Commission of Southern Nevada (RTC), FAST successfully implemented a solution to resolve the compatibility issues between the different EVP systems deployed in the region. The effort has led to the development of a regional encoding scheme based on the unified technology platform. Future considerations include the potential standardization of the system specification and the implementation of the regional encoding scheme for all agencies, including the low priority traffic signal application for transit operations.

Description of Practices:

The RTC planning region has been one of the nation's fastest growing areas in the past decade. On average, FAST logs more than 3,000 high priority preemptions each day on the centralized traffic management system. The RTC estimated that the actual number of preemption events to be much larger because not all EVP-equipped intersections are connected to the central system.

FAST cited the following EVP operational concerns in the RTC region:

- Degradation of traffic flow and increased congestion, with possible safety implications for the traveling public, resulting from the large number of preemptions.
- The unauthorized preemptions by illegally purchased optical preemption emitters and unauthorized users driving an EVP equipped public vehicle. Member agencies observed taxi drivers using the illegally purchased emitters in the field.
- Potential false calls and false preemption service caused by unusual lighting conditions, such as emitter signals or background light reflecting off signs or windows. This problem can be avoided by encoding the EVP system which enables the verification of emitter ID before granting the preemption.
- Anticipated significant increase in the EVP equipped fleet from the Las Vegas Metropolitan Police Department to more than 1,000 police cruisers, in addition to the fire and ambulance vehicles.

The regional encoding requirement of the EVP systems was initially established in 2004. FAST has been the manager of this encoding scheme. As the managing agency of FAST, the RTC developed the following guidelines to implement the regional preemption encoding scheme:

- Standard Specifications: The 3M (later became GTT) Opticom was specified as the standard for the region. The guidelines required the model 700 (i.e., 700 series) equipment (phase selector) for all future purchase…. citing "since using encoding requires that all equipment are of the same manufacture"
- Standard Panel: Develop a standard panel for terminating preemption wiring in the traffic signal cabinet that can be used by all agencies to facilitate troubleshooting and retrofitting of the existing cabinets.
- Green Monitoring: Provide communication to the Opticom phase selectors (in the traffic signal cabinet) to enable remote monitoring and access to the EVP system logs.
- Addresses: Programming the phase selectors with the same intersection ID used in the central traffic signal management system. This simplifies the management of the field EVP system as it uses the same ID as the signalized intersections.
- Vehicle Maintenance List: All agencies responsible for maintaining and coding their emitters are required to maintain a list of vehicles, associated vehicle ID, and assigned EVP code. The purpose is to allow monitoring EVP usage and "verify that the user is a valid vehicle". Traffic agencies are supplied with the vehicle maintenance list to ensure these codes are programmed as valid in the preemption equipment.

Preemption Encoding Scheme:

To facilitate the migration to an encoded EVP system, FAST developed a common classification and encoding scheme for all agencies to avoid duplicate vehicle class and ID from being used by different agencies. Using the encoding convention provided by the Opticom EVP system, a table depicting the encoding scheme was developed. The key data fields in the table include:

- Vehicle Class (0-9)
- Vehicle ID (0-999)
- Relative Priority (0-9)[39]
- Description of Agency[40]

Since Opticom supports separate coding for high and low priorities, two encoding tables were developed, one for the high priority emergency vehicle preemption, and the other for the low priority transit Traffic Signal Priority (TSP).

The high priority (emergency vehicle preemption) encoding table is developed based on the following guidelines:

[39] Relative priority feature is only available in newer Opticom 700 series phase selector cards. This feature is not currently used in the encoded EVP systems in the MAG region.
[40] Description of agency is not encoded in the emitter and needs to be maintained in the vehicle maintenance list.

- Dedicated vehicle class 0 for maintenance (e.g., Clark County, Henderson County, Las Vegas, and North Las Vegas Department of Transportation).
- Each fire department is assigned with its own vehicle class (e.g., Clark County Fire Department, Henderson Fire Department, Las Vegas Fire Department, and North Las Vegas Fire Department).
- Each police department is assigned with its own vehicle class with the exception of the Las Vegas Metropolitan Police which is expected to exceed 1,000 vehicles, the maximum number of ID allowed for a vehicle class. Two vehicle classes were designated for the Las Vegas Metropolitan Police.
- The relative priority for all maintenance vehicles (vehicle class 0) is set to be 1.
- The relative priority for all fire and paramedic agencies is 9, the highest priority allowed. Priority 7 to 9 is allocated to fire and ambulance for future determination of relative priorities among the agencies.
- The relative priority for police agencies is given a 6 across the entire region. Priority 2 to 6 is assigned to police for future determination of relative priorities among the agencies. The police vehicles always have lower priority than the fire and ambulance vehicles, in the case of concurrent preemption requests to the same intersection.

The low priority (transit signal priority) encoding scheme is less complicated because RTC is the only anticipated user. The guidelines for the low priority encoding table include:

- Dedicated vehicle class 0 for maintenance (Clark County, Henderson County, Las Vegas, and North Las Vegas Department of Transportation).
- Vehicle Class 1 is assigned for the Bus Rapid Transit (BRT) service.
- Vehicle Class 2 is assigned to the CAT buses.
- The remaining Vehicle Classes 3 to 9 are unassigned and reserved for future transit applications.
- The relative priority for all maintenance vehicles (vehicle class 0) is set to be 1.
- The relative priority of the BRT (vehicle class 1) is 7 which is higher than the 6 designation for the regular CAT buses (vehicle class 2).

Issues Associated with Encoding

RTC identified the following issues associated with the changeover to encoding.

- There are costs associated with the changeover to encoding. Preemption equipment deployed in the Las Vegas area is not all from the same manufacturer. Using encoding requires that all equipment be from the same manufacturer. Using encoding requires replacement of numerous vehicle emitters and some intersection hardware. This requires specifying a single manufacturer for all new installations (i.e., GTT Opticom).

- A significant number of older model 3M (GTT) preemption equipment on the street would need to be upgraded to 700 series equipment (phase selector).
- There is added work for the vehicle maintenance technicians in each agency that are responsible for installing the vehicle emitters. A list of vehicle ID numbers and associated Opticom (emitter) ID numbers needs to be maintained and shared with traffic signal maintenance staff.
- During changeover, there may be a short time period when not all agencies' emergency vehicle emitters will work in different jurisdictions. If one agency upgrades to encoding, and another agency does not program the emitters, the vehicles may not be able to place preemption calls across agency boundaries.

Role of RTC:

The role of RTC in implementing the regional encoding scheme includes:

- Maintaining the regional EVP encoding tables.
- Providing updates to the encoding tables based on member agencies' input.
- Facilitating all EVP operations related discussions in the region.
- Developing guidelines regarding EVP implementation and operations for adoption by the member agencies. Such guidelines may be of a policy and/or technical nature. Examples of the technical guidelines include the standard specifications (e.g., specifying Opticom 700 series phase selectors) and development of standard panel (i.e., standard EVP wiring terminations in the traffic signal cabinet) in support of troubleshooting and retrofitting of traffic signal cabinets by different agencies.

3.1.3 Case Study: Harris County, Texas

Synopsis:

As the nation's third largest county, Harris County encompasses the greater Houston metropolitan area. In 2008, a pilot study was carried out to evaluate new EVP technologies which aim to address the shortcomings of the optical-based system. Future considerations include the potential systematic approach of evaluating alternative technologies and the institutional process to adopt the recommendations for regional deployment.

Description of Practices:

Harris County manages the traffic signal systems for several jurisdictions through an Inter-Governmental Agreement (IGA). Over the past decades, Harris County cited several shortcomings associated with the optical-based EVP system that was widely deployed in the region, including:

- High maintenance requirements – cleaning and calibration of the detectors on the mast arm due to the line-of-sight nature;
- Traffic impeding during maintenance;
- Cannot coordinate preemption request with the adjacent intersections;
- Not integrated with the central traffic signal management system.

Based on the aforementioned concerns, Harris County explored the alternative EVP technologies and identified the GPS-based system from EViEWS. A multi-year pilot deployment and evaluation were conducted along Louetta Road in north Harris County. The pilot deployment tested the EViEWS GPS-based EVP system with the following objectives:

- Providing remote management capabilities of the system from Houston TranStar;
- Enhanced situational awareness for participating emergency responders;
- Enhanced advance notification of the need for emergency vehicle preemption treatment;
- Minimal disruption to existing coordinated signal timing;
- Implementation of national data sharing standards between response vehicles, traffic management systems, and emergency dispatch systems;
- A migration plan to allow for long term data communications and routing capabilities of emergency vehicles.

The evaluation of the pilot deployment was completed in 2008 with favorable findings in support of the deployment of the GPS-based system in the region. The following efforts were made to advance the decision:

- Harris County revised its policy to disallow the further deployment of the optical-based EVP system.
- The evaluation recommendations for adopting the EViEWS EVP system were approved by Emergency Services District (ESD) in the Harris County area. An example of the endorsement letter to the Harris County Commissioner's Court is provided in Appendix B.
- With court approval, the recommendations to deploy the EViEWS GPS-based EVP system were adopted by the individual cities through the IGAs with Harris County.

An agreement between Harris County and Emergency Service District (ESD) 11 was approved by the Harris County Commissioner's Court in July 2008, allowing Harris County to work cooperatively with ESD 11 in Northwest Harris County to install and operate an emergency vehicle preemption system on traffic signals maintained by Harris County.

The EVP system users are limited to first responders, large fire apparatuses and ambulances responding to emergency situations within the confines of ESD 11. The agreement enabled ESD 11 to purchase the necessary equipment to allow emergency vehicles to communicate vehicle information to traffic signals and provide incident data from ESD 11 dispatch centers to Houston TranStar.

To facilitate the installation of the GPS-based EVP system in different jurisdictions, Harris County developed several documents in support of the technical implementation and institutional process:

- **Harris County Emergency Vehicle Priority System Requirements – Local Controller Firmware:** Defined how the traffic signal controller interacts with the GPS-based EVP messages, including check-in, check-out, and policy for terminating signal phase, etc. (see Appendix C)
- **Harris County Emergency Vehicle Priority System Requirements – GPS System:** Defines the behavior of the GPS-based onboard unit (see Appendix D)
- **Court order for executing Inter Governmental Agreement for deploying the EVP:** A boiler plate for adoption by different local jurisdictions (see Appendix E)

The controller and GPS requirements document (Appendix C and D) highlighted several advantages of the GPS-based system over the optical-based system, including:

- Use travel time to intersection (estimated time to arrive) as opposed to fixed distance (pre-determined light sensitivity level) for requesting preemption

- Minimum of 80 seconds of advanced notice (cannot be specified with the optical-based system)
- Vehicle ID is visible from traffic signal controller front panel and in the controller logs
- Left turn request can be passed from the onboard GPS to the intersection to determine if the green left turn arrow (if available) needs to be served as part of the preemption phase
- Left turn request can be forwarded to the next intersection
- All messages are passed from the field EVP device to the controller via Ethernet

The standardization of system functions and specifications has been instrumental in the success of Harris County's EVP deployment involving multiple local jurisdictions.

3.2 EVP System Management

3.2.1 Case Study: East Valley EVP Working Group of Phoenix Area, Arizona

<u>Synopsis</u>:

The East Valley EVP Working Group originally started in 2008 to coordinate EVP operations in the Cities of Chandler, Mesa, Tempe, and Town of Gilbert. The Working Group collaboratively developed an encoding scheme for encoding their EVP systems and coordinated details about the traffic signal phase provided during the preemption. The encoding scheme also includes all emergency agencies in the greater Phoenix metropolitan area. Over the years, the Working Group has expanded to include more East Valley jurisdictions that share common borders. Future considerations include the potential development of the regional encoding scheme and EVP data management in support of troubleshooting, performance monitoring, and policy decision making.

<u>Description of Practices</u>:

Currently, the East Valley EVP Working Group is comprised of the fire departments and traffic operations personnel of the Cities and Towns of Apache Junction, Fountain Hills, Guadalupe, Scottsdale, Chandler, Town of Maricopa, Mesa, Sun Lakes, Gilbert, Queen Creek, and Tempe. The goals of the East Valley EVP Working Group are to:

- Standardize the way traffic signals operate in the East Valley;
- Allow use of encoded traffic preemption systems to eliminate unauthorized users;
- Allow use by ambulance companies with oversight by the appropriate fire department;
- Improve response times for automatic aid calls;

- Reduce liability to the cities.

Based on the common technology platform[41] (GTT Opticom), the East Valley EVP Working Group collaboratively encoded their EVP systems with the following objectives:

- Prevent the activation of EVP by elicit emitters
- Enable the EVP usage data logging in support of:
    - Troubleshooting (resolve complaints of EVP not working)
    - Detecting unauthorized use of EVP equipment
    - Assessing traffic network impact
- Coordinate emitter encoding allocations so each agency uses a unique block of IDs to prevent duplication.
- Coordinate the preemption signal phasing to improve consistency across jurisdictions

Based on the encoding scheme created by City of Mesa in 1994, the East Valley Working Group now maintains an expanded encoding scheme for high priority preemption including ambulance, fire, and police departments in the greater Phoenix area. In 2010, with the debut of Bus Rapid Transit (BRT) service in the East Valley, a low priority coding scheme was developed to facilitate the Transit Signal Priority (TSP) that share the use of the EVP infrastructure along the BRT route. Instead of preempting the traffic signal, the low priority TSP request is served by either providing an early green or extending the existing green phase to facilitate the passage of the transit vehicle. The low priority request does not affect the emergency vehicle preemption because the high priority preemption request automatically overrides the low priority calls should there be concurrent requests.

Based on the GTT Opticom, there are two components to the EVP code, namely, Vehicle Class (0-9) and IDs (0-999) per Vehicle Class. That is, the Opticom system can be programmed to support up to 10,000 unique IDs using the combination of Vehicle Class and ID fields. In addition, the newer hardware (e.g., 700 series phase selectors) can also support the relative priority that can be assigned to each encoded emitter.

The East Valley Working Group divided up the 10 vehicle classes by type of operation.

- Vehicle class 0-1: Ambulance
- Vehicle class 2: Reserved for future applications
- Vehicle class 3-7: Fire
- Vehicle class 8-9: Police

[41] Towns of Gilbert and Queen Creek deployed the TOMAR optical-based EVP system that is not compatible with the encoded GTT Opticom system deployed by the rest of the East Valley EVP Working Group member agencies.

A Code Assignment List was developed based on the following:

- Class 0 code 0 is left unassigned. This locks out the illegally purchased emitters, un-encoded GTT emitters, and TOMAR emitters. The Working Group allows the individual cities to decide if they want un-encoded emitters to activate their signals. Class 0 and code 1 is also unassigned because this is the default value used for GTT Opticom emitters.
- To accommodate the large number of older 500 series phase selectors still deployed in the field, the coding method is compatible with the 500 series while allowing the flexibility to use the additional features of the 700 series (e.g., allowing setting the relative priority (0-9) and setting valid codes individually[42]).
- The Code Assignment List allocates blocks for each emergency agency based on the assumption that larger cities would have more emitter equipped apparatus. For smaller jurisdictions, a minimum of 100 vehicle ID codes is assigned per agency.
- Classes 0 and 1 are reserved for ambulances due to the potentially large number of service providers, vehicles, and communities involved. The ambulance classes require further definition to assign codes to the individual ambulance companies. The assignment should be done in a manner that permits individual cities to decide which ambulance companies to allow access within their jurisdictions. Having ambulances in their own class also allows cities to apply "relative priority" should they choose to.
- Two dedicated vehicle classes are assigned to police. With the 700 series phase selector's ability to assign relative priority, this allows an individual city to decide if a police vehicle should be of lower priority than fire apparatus, in the case of concurrent requests at an intersection.
- When interpreting event logs from the phase selectors, there needs to be a way to correlate the Opticom emitter codes (vehicle class, vehicle ID) with the vehicle numbers (e.g., those assigned using the "Valley Fire Chiefs Mutual Aid Numbering System"). That is, there is a need to maintain a regional database which relates vehicle IDs to emitter codes. GTT's Opticom Central Management Software (CMS), used by several East Valley jurisdictions, includes built-in management of vehicle IDs and accommodates regional operations involving multiple agencies.

The key to the successful implementation of this Code Assignment List is that each agency (vehicle maintenance) programs the emitters using unique IDs within the assigned block. This unique ID makes it possible to examine system logs to verify that a specific ID (vehicle) was

[42] For 500 series phase selectors, the valid codes were assigned as a single block with a low (starting) and high (ending) code number. The 700 series allows any combination of codes to be made valid.

present at an intersection on a given date and time. The ability to capture positive ID is very useful in troubleshooting signal problems.

As the lead agency of the East Valley EVP Working Group, the City of Mesa routinely utilizes the EVP event logs for various system monitoring and analysis, including:

- In response to trouble calls from the fire department, Opticom Central Management Software is used to retrieve and analyze the EVP event logs. City of Mesa's centralized traffic signal management system, Centracs, is used in conjunction for troubleshooting. A reported failed actuation can be investigated in two aspects: 1) if the Opticom system received the preemption request (through EVP event logs), and 2) if the controller actually received the preemption call from the phase selector (through Centracs traffic signal controller logs). In addition, the Opticom Central Software can be used to review or set the phase selector configuration parameters in support of maintenance and troubleshooting.
- In conjunction with Valley Metro, provided assistance in configuration and logging of the low priority transit Traffic Signal Priority (TSP) event logs in support of system monitoring and assessment.

3.3 Preemption Treatment

3.3.1 Case Study: State of Minnesota

Synopsis:

The State of Minnesota is one of the nation's EVP system early adopters[43]. The Twin Cities area began implementing optical-based EVP systems in the mid 1960's. They included use of four-way confirmation lights as part of EVP operation in the early 1970's. EVP operations, including preemption phase uniformity and confirmation indicator light standards, are defined in the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD). The EVP implementation in St. Paul is provided to exemplify the conformity brought along by the MMUTCD.

Description of Practices:

As a supplement to the Federal Manual on Uniform Traffic Control Devices (MUTCD), the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD)[44] (January 2014) includes sections dedicated for emergency vehicle preemption operation.

- 4D.27 Preemption and Priority Control of Traffic Control Signals (amended by Minnesota)
- 4D.27.1 Operation of Preemption (new sub-section added by Minnesota)

Section 4D.27 defines the standard of strobe actuated preemption and priority detection as "*the system shall respond to emitter frequencies*":

- Preemption - 14.035 Hz ± 0.05 Hz
- Priority - 9.639 Hz ± 0.03 Hz

These frequencies are the common standard used by GTT (Opticom), TOMAR (STROBECOM) and other compatible optical-based EVP systems.

Section 4D.27.1, Operation of Preemption, contains the following standards:

- Traffic signal phase transition into and out of preemption control;
- Requirements that all newly constructed signals be wired for Emergency Vehicle Preemption (EVP), including confirmation indicator lights;

[43] 3M is based in the state of Minnesota.
[44] Minnesota Manual on Uniform Traffic Control Devices (MUTCD) http://www.dot.state.mn.us/trafficeng/publ/mutcd/

- Preemption signal phase for two-phase, protected/permissive, freeway interchange, and protected operations.

The requirement for newly constructed signal stated "*All newly constructed signals shall be wired for Emergency Vehicle Preemption (EVP). This includes running the necessary electrical conductors to the base of each pole or terminating in the mast arm as appropriate."*

The standard further defined the type and operations of the confirmation indicator light as follows.

Traffic signals with EVP shall use confirmation white/clear indicator lights. The confirmation lights shall only be used during signal preemption.

- A steady confirmation indicator light facing an approach shall mean that the authorized emergency vehicle preemption has been received by the signal controller for that approach.
- A flashing confirmation indicator light facing an approach shall mean that the signal controller has received a conflicting preemption call and cannot respond to the preemption from the authorized emergency vehicle on the approach.

The Minnesota MUTCD explained that the purpose of the confirmation indicator light is *"to verify to the authorized emergency vehicle driver that <u>the controller has received the preemption call</u>, to indicate which approach will be served under the preemption…*" and "*The confirmation indicator light <u>does not assign any right of way at the intersection</u>. The driver of the emergency vehicle is required to respond to the traffic control signal indications in accordance with applicable statutes and ordinances.*"

MMUTCD provides the standards of the preemption signal phase for two-phase (Figure 16), protected/permissive (Figure 17), and protected only (Figure 18) locations.

For two-phase (permissive left turn only) intersections (Figure 16), the authorized emergency vehicle's approach shall receive a steady confirmation light along with the opposing approach. The controller shall cycle through to bring up the circular green indications. The conflicting approaches shall receive flashing confirmation lights and circular red indications.

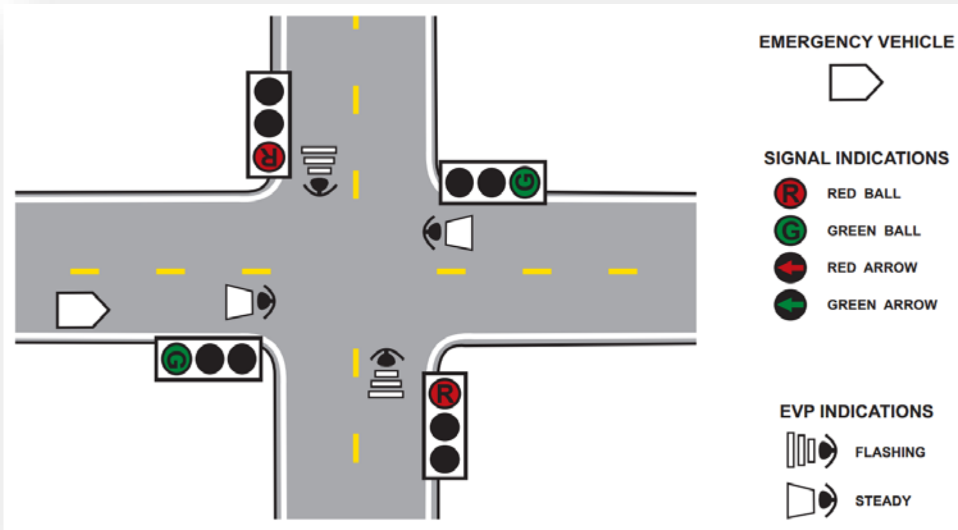


Figure 16. MMUTCD EVP - Two Phase Operation

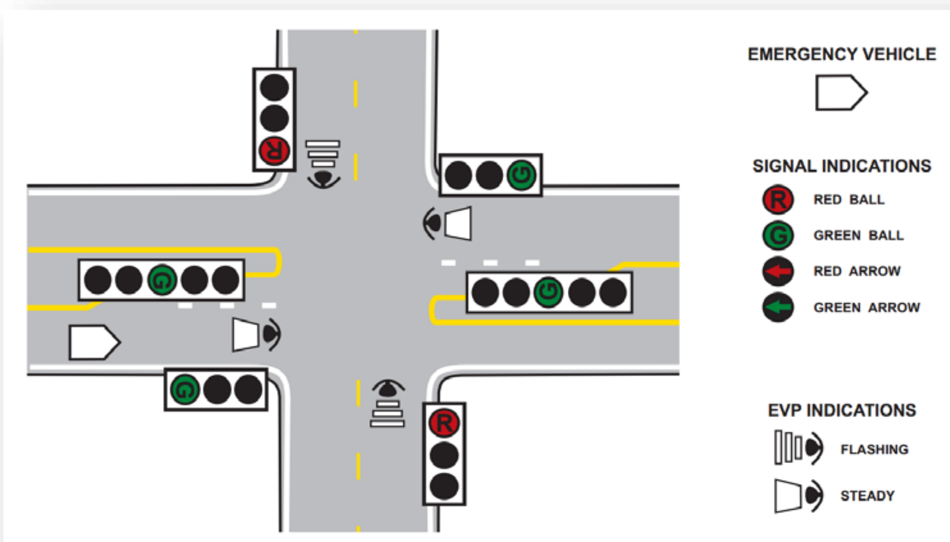


Figure 17. MMUTCD EVP - Protected/Permissive Operation

The rationale of protected/permissive operations (Figure 17) is explained as follows. The authorized emergency vehicle's approach shall receive a steady confirmation indication light along with the opposing approach. The controller shall cycle through to bring up the circular green signal indication. The left turn green arrow is not given on the preempted approach since a permissive green ball for the opposing flow would have to be terminated first. An opposing left turner, seeing the signal go to yellow, might mistakenly assume that the preempted approach was also yellow, and turn into the oncoming traffic proceeding on a green. This is referred to as a "left turn trap." To avoid this, the left turn green arrow is not given to any approach. The operation of this intersection, under preemption, is similar to that of a two-phase intersection. Conflicting approaches shall receive flashing confirmation indication lights and circular red signal indications.

An option for handling a protected/permissive location was provided in the MMUTCD. The authorized emergency vehicle's approach may receive a steady confirmation indicator light, a protected left turn green arrow, and a circular green, with opposing and conflicting approaches receiving flashing confirmation indicator lights and red indications, if the traffic signal <u>first transitions to an all red indication for all approaches</u>. The drawback of this option is that "transitioning to an all red indication for all approaches" will incur additional delay before the green indication can be provided to the emergency vehicle. This option may be considered for low speed locations where it takes longer for an emergency vehicle to arrive at the preempted intersection. In Arizona, no jurisdiction has adopted this option due to the overall higher operating speed.

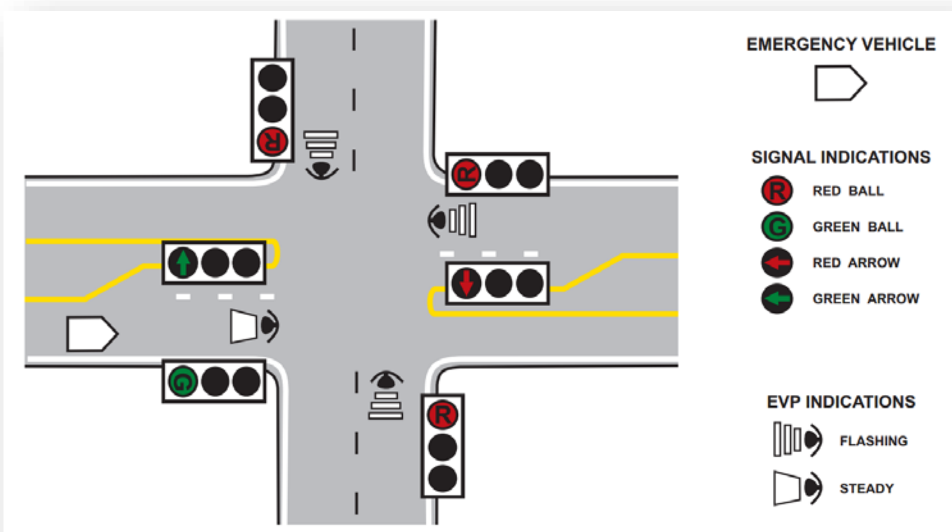


Figure 18. MMUTCD EVP – Protected Operation

For protected intersections (Figure 18), the authorized emergency vehicle's approach shall receive a steady confirmation indicator light, a protected left turn green arrow, and a circular green. The opposing and conflicting approaches shall receive flashing confirmation indicator lights and red indications.

The operation of the confirmation indicator light in the MMUTCD is similar to but different than the City of Phoenix's implementation which also deployed the 4-way white/clear flood light. The difference is that MMUTCD requires that the confirmation indicator lights for all non-preempted approaches be flashing, and the preempted approach to receive a solid indication; whereas, in the case of Phoenix, the lights of non-preempted approaches will stay off (dark) and only flash if there is a concurrent request from the non-preempted approach. Flashing indicates to an emergency vehicle operator that the right-of-way has been denied due to an earlier preemption request.

Table 6 compares the EVP standards (Section 4D.27 Preemption and Priority Control of Traffic Control Signals) between the Minnesota, Arizona, and Federal versions of the MUTCD.

Table 6. MMUTCD EVP Standards Compared

Section 4D.27 of MUTCD	Minnesota (2014)	Arizona (2009)	FHWA (2009)
Signal indication sequence during the transition into preemption control	Yes	Yes	Yes
Signal indication light sequence during preemption control and during the transition out of preemption control	Yes	Yes	Yes
Requirement of EVP wiring for new signal construction	Yes	No	No
EVP emitter frequency standard	Yes	No	No
Specification of confirmation indicator light	Yes	No	No
Operation of preemption signal phase and confirmation indicator light	Yes	No	No

Example of City of St Paul's (Minnesota) EVP Implementation

The Twin Cities of St. Paul and Minneapolis make up the largest metropolitan area in the state of Minnesota. City of St. Paul is one of the nation's earliest adopters of the optical-based EVP system. In 1969, optical-based EVP system technology was installed at 28 intersections in St. Paul as part of their efforts to reduce emergency vehicle-related crashes. By 1976, over 90% of its 308 intersections were equipped with the EVP system. In 1972, the 4-way clear/white flood light type of the confirmation indicator lights were deployed and became part of the standard EVP operation. Currently, all 375 signalized intersections in St. Paul are equipped with the optical-based EVP and confirmation indicator lights. The users of the EVP system include fire department, ambulance service, and police. St. Paul is one of only a few jurisdictions in the country that provides preemption access to all police vehicles.

Figure 19. EVP Detector and Confirmation Indicator Light (City of St. Paul)

The majority of the traffic signal controllers are Type 170 along with some ASC/3 RM controllers in Type 332 and 332D cabinets. St. Paul is currently using the Centracs centralized traffic signal management system for managing its traffic signals in the field.

The implementation of the EVP system in St. Paul has closely followed the MMUTCD standards. In St. Paul, the confirmation indicator lights are implemented by the traffic signal controller, as opposed to the preemption detection cards. The rationale of using the traffic signal controller to control the confirmation indicator light was explained in the MMUTCD that "the purpose of the confirmation indicator light is to verify to the authorized emergency vehicle driver that the controller has received the preemption call". The possible issue of letting the preemption detector card control the confirmation indicator light is that if the controller failed to receive the request from the preemption detection card, the confirmation indicator lights will still be working without the intersection being preempted.

For signals with protected only left turn phasing, the Minnesota Manual on Uniform Traffic Control Devices (MMUTCD) requires the left turn green phase to come up with the through phase green during an EVP call; in this case the solid confirmation light is on for this approach, and all other approaches would flash.

On an intersection with protected/permissive left turn phasing or permissive only intersections, an EVP call can request the through phase and the opposing phase (e.g., phases 2 & 6); in this case the confirmation light would be solid for phases 2 & 6, and EVP confirmation lights for phases 4 & 8 (i.e., through phases for the cross street) would flash. This second case (i.e., green indication for both through phases) would be the more common type of operation in St. Paul and is accepted by the Emergency Responders. A vast majority of the intersections in St. Paul are low speed (30 mph) and have 2 lanes of approach and occasionally left turn lanes. Engineering judgment was applied to each site in light of the geometry and speed of the intersection. In recent years, the original incandescent flood lights were replaced with the LED Flood (PAR 38, 7.3W), which dramatically improved the reliability and reduced power consumption.

4. FUTURE CONSIDERATIONS

To begin to address the issues and challenges concerning EVP operations in the MAG region, this section provides a potential guideline to facilitate discussion for the next steps. It is envisioned that the next project involving EVP operations will include a workshop, or series of workshops, bringing together agency representatives of both traffic engineering and fire departments for generating consensus on future considerations of EVP practices. The goal of the anticipated workshop(s) is to form regional consensus for improving and standardizing EVP operations in the MAG region. If there is agreement by all parties for any or all of the concerns, the unified vision(s) would include regional standards to be reviewed and adopted through the formal MAG approval process. This would establish regional consistency and provide guidelines for all future EVP implementation by MAG member agencies. Should consensus not be achieved in these planned future efforts, the “do nothing” option would accepted and current practices would be maintained until better solutions to the issues and challenges emerge.

In anticipation of these next steps, this section identifies key issues and challenges concerning EVP operations in the MAG region that need to be fully addressed in future consensus-building exercises. These focus areas include:

- System interoperability
- Preemption operations
- Regional EVP coordination

4.1 System Interoperability

As there are currently two EVP systems deployed in the MAG region, a potential solution for system interoperability is for regional partners to agree to adopt one system for future deployment. As EVP operations are maintained and upgraded, agencies would migrate over to the one system, updating equipment as funding becomes available. This solution would require an undetermined amount of time for the migration process of those agencies switching to the adopted EVP system. As life cycles of older equipment ended, agencies would procure new EVP equipment from the one accepted system.

The potential process for implementing a single EVP system solution involves the following steps:

- **Collect EVP Inventory Data** - Gather detailed inventory of current EVP equipment deployed in the MAG region with specific focus on:
  - Number of EVP-equipped emergency vehicles per jurisdiction, per system, and encoding status

  - Un-encoded TOMAR and GTT field equipment
  - TOMAR and GTT field equipment that do not support the encoding feature per jurisdiction
- **Develop Regional Consensus** - Conduct a workshop with regional partners to select and approve the single system solution. The components of the workshop include:
  - Identification of the pros and cons for EVP operations and maintenance for each system, with the potential to review other available off-the-shelf systems.
  - Quantity and estimated cost for installing new equipment for each jurisdiction required to migrate to a new system.
  - Benefit-cost analysis of migration to each EVP system, including but not limited to procurement, installation, configuration, acceptance testing, operation, and maintenance.
  - Agreement by all parties on a solution.
- **Adopt Recommended Solutions** – Once approved by the MAG ITS Committee, the agreed upon solution would be approved and adopted through the MAG committee process so member agencies can move forward with the implementation of the solution. In lieu of complete agreement, the “do-nothing” option will be exercised and there will be no change to the current practice.
- **Identify Implementation Schedule** – Member agencies and MAG staff coordinate to program projects for implementing the solution.

Alternatively the MAG region could collaboratively determine the method to achieve the co-existence of current EVP systems and identify available technologies that allow for system interoperability. This approach may include implementation of dual or hybrid emitters on the emergency vehicles. Dual emitters would be capable of emitting both encoded GTT and encoded TOMAR signals and thus can preempt traffic signals equipped with both brands of EVP systems regardless of their encoding status. The merit of this approach is that it does not require equipment replacement on the traffic signal side of the EVP installation. The basic concept of dual emitters is illustrated in Figure 20.

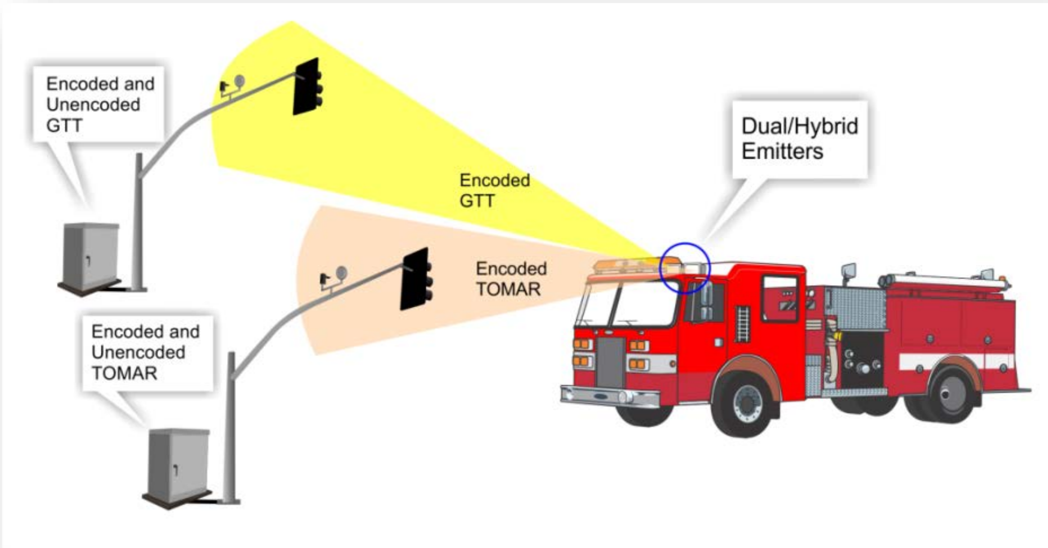


Figure 20. Dual Emitter Concept Illustrated

For example, a Phoenix fire vehicle equipped with an existing un-encoded TOMAR emitter would be outfitted with an additional emitter capable of transmitting GTT signals encoded based on the regional coding convention set forth by the East Valley EVP working group. The additional emitter would allow the Phoenix fire vehicles to preempt the encoded traffic signals in the neighboring cities such as Tempe, Mesa, and Chandler. In addition, the unique emitter ID could be properly logged by the encoded field EVP equipment in support of usage monitoring.

The specification of the dual/hybrid emitters would be evaluated based on the technical feasibility and cost, including:

Option 1: Deploy both brand of emitters on an emergency vehicle (dual emitters)

Option 2: Procure an emitter that is capable of transmitting the encoded signal of both GTT and TOMAR systems (hybrid emitters). Patents may be in place already for this technology; this may limit or even prohibit this solution.

In order to operate and maintain the two systems, this solution may be cost prohibitive. It might be utilized as an intermediate solution, should one system be adopted by the region and a transition period occurs to standardize EVP operations. The implementation of this system compatibility solution could take place in two stages. Table 7 summarizes the respective actions needed in each stage.

Table 7. System Compatibility Implementation Stages

EVP Systems		Stage 1	Stage 2
Cities with Un-encoded TOMAR	Emergency Vehicles	Install encoded GTT emitters; Encode existing TOMAR emitters	No change
	Intersections	No change	Encode all TOMAR field equipment
Cities with Un-encoded GTT	Emergency Vehicles	Install encoded TOMAR emitters; Encode existing GTT emitters	No change
	Intersections	No change	Encode all GTT field equipment
Cities with Encoded GTT	Emergency Vehicles	Install encoded TOMAR emitters	No change
	Intersections	No change	No change

Stage 1: Implement dual emitters on emergency vehicles.

- Implement new GTT-compatible emitters on vehicles currently equipped with a TOMAR emitter. The new GTT-compatible emitter will be encoded based on the regional coding convention, enabling the vehicle to preempt encoded GTT field equipment located in adjacent jurisdictions.
- Encode all TOMAR emitters using the regional coding convention established for the jurisdictions.
- Encode the un-encoded GTT emitters.
- Install an encoded TOMAR emitter on emergency vehicles currently equipped with a GTT emitter.

Stage 2: Encode all TOMAR and GTT field equipment. It is expected that this effort may also involve replacing some early models of EVP equipment that do not support encoding features.

If a hybrid emitter is used, the stage 1 will involve the replacement of the existing emitters with the hybrid emitter encoded for both types of systems. The hybrid emitter will be encoded based on the regional coding convention.

The potential process for implementing the system compatibility solution involves the following steps:

- **Develop Technical Specification** - Work with system vendors to assess the feasibility of hybrid emitters and develop the cost estimate for both dual emitter and hybrid emitter solutions. This can be done through a Request for Information (RFI) to all EVP system developers.

- **Collect EVP Inventory Data** - Gather detailed inventory of current EVP equipment deployed in the MAG region with specific focus on:
  - Number of EVP-equipped emergency vehicles per jurisdiction, per system, and encoding status
  - Un-encoded TOMAR and GTT field equipment
  - TOMAR and GTT field equipment that do not support the encoding feature per jurisdiction
- **Develop Regional Consensus** - Conduct a workshop with regional partners to select and approve the dual/hybrid-emitters solution. The supporting input to the workshop includes:
  - Quantity and estimated cost for installing dual emitters for each jurisdiction
  - Estimated costs for encoding TOMAR and GTT field equipment and possible equipment replacement per jurisdiction
- **Adopt Recommended Solutions** – The agreed upon solution would be approved and adopted through the MAG committee process so member agencies can move forward with the implementation of the solution. In lieu of complete agreement, the "do-nothing" option will be exercised and there will be no change to the current practice.
- **Identify Implementation Schedule** – If approved by the MAG ITS Committee, program projects for implementing the solution.

4.2 Preemption Operations

For future consideration the following potential solutions are provided to improve the consistency of traffic signal operations during preemption across the MAG region.

<u>Control of Confirmation Light</u>

For existing and any future installations, confirmation lights should be controlled by the traffic signal controller, as opposed to the preemption detector card (e.g., phase selector for GTT, Optical Signal Processor for TOMAR). The concern of letting the preemption detector card control the confirmation light is that if the controller failed to receive the request from the preemption detector card, the confirmation lights would activate without the intersection operating under preemption conditions. Figure 21 illustrates the recommendation for confirmation light configuration. As this configuration involves safety implications for EVP users, this is a recommended practice.

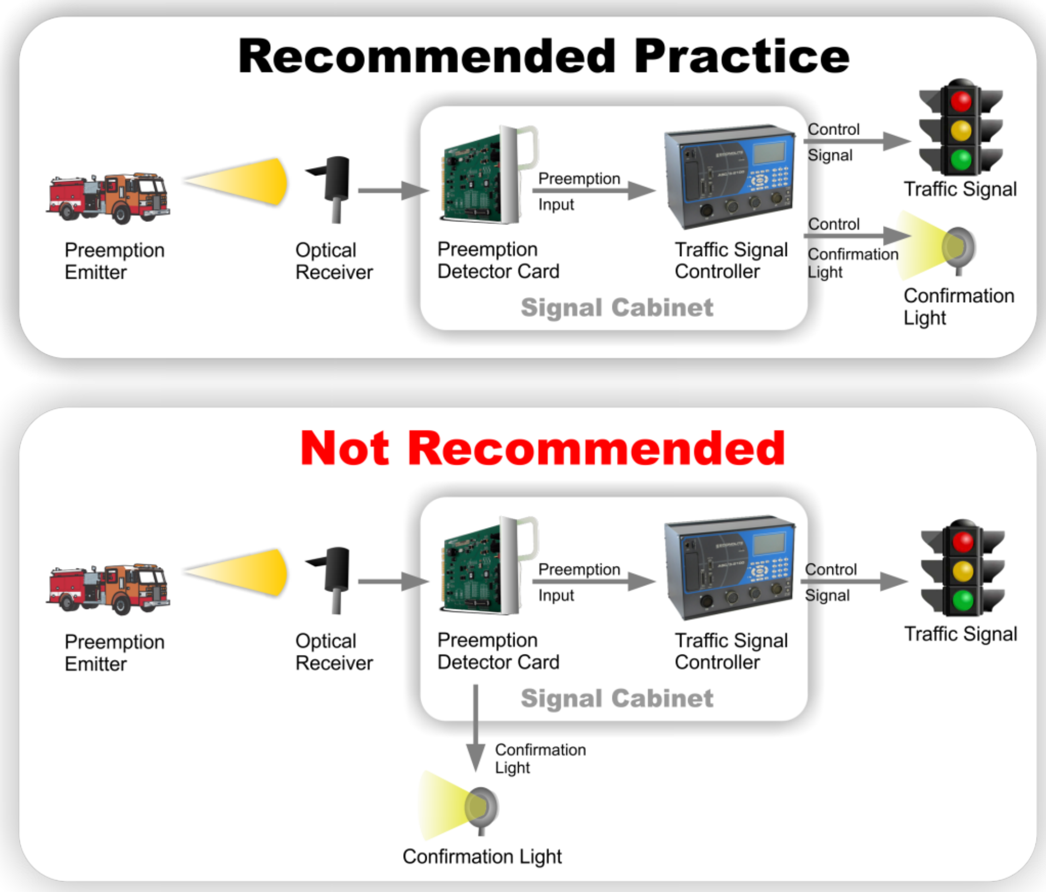


Figure 21. Recommended Confirmation Light Control Practice

Encoding

It was identified through discussions with project stakeholders that encoding varied among MAG member agencies. Those agencies that encoded EVP emitters prefer the practice; those that did not encode have limited resources to monitor and maintain the encoding policy. As a regional option encoding is discussed in detail under system interoperability.

For future consideration the regional discussion at a potential workshop on encoding would focus on the merits of encoding EVP emitters and maintaining the encoding database along with any potential analysis of EVP system users. It is vitally important that agencies attending this workshop would include Fire and Police Departments for this discussion to gain their valuable input and viewpoints for this discussion.

Should consensus on encoding be agreed up by all parties, the encoding efforts should expand on the policies already established by the East Valley EVP Working Group. Any consensus for a solution would also necessitate an educational component to reach out to system operators and maintenance technicians. An agreed upon solution would be approved and adopted through the MAG committee process so member agencies can move forward with the implementation of the solution. In lieu of complete agreement, the "do-nothing" option will be exercised and there will be no change to the current practice.

Consistent Preemption Traffic Signal Phase

There are two predominant practices that result in inconsistent traffic signal phases provided during preemption operations in the MAG region. For future consideration through a workshop consensus process, regional partners and stakeholders would collaboratively discuss and select one of the following options as the regional standard practice.

Option 1: Concurrent through phase indications are given to both the approaching emergency vehicle and the opposing direction. The conflicting perpendicular approaches will be given the red indications. This applies to the permissive only, permissive/protective, and protected only left turn locations.

Option 2: Through and left turn indications are provided to the direction of emergency vehicle, and red indications are provided to all other approaches. This applies to the permissive/protected and protected left turn only locations. At permissive only locations, the concurrent through phase indications are provided.

The discussion would also standardize the preemption operation for flashing yellow and other scenarios (e.g., leading and lagging left turn and unusual geometry) that require special considerations. It is vitally important that agencies attending this workshop would include Fire and Police Departments for this discussion to gain their valuable input and viewpoints for this discussion. Any consensus for a solution would also necessitate an educational component to reach out to system users. An agreed upon solution would be approved and adopted through the MAG committee process so member agencies can move forward with the implementation of the solution. In lieu of complete agreement, the "do-nothing" option will be exercised and there will be no change to the current practice.

Regional Adoption of Confirmation Light Uniformity

As the use of confirmation lights are currently optional and infrequently deployed throughout the MAG region, regional adoption of standardization of confirmation lights would be for any future installations. This would provide uniformity for EVP system users. Regional partners would collaboratively evaluate and determine the type of confirmation light to use as the regional standard should an agency opt to include confirmation lights in the EVP system installation. The options include but are not limited to:

- Directional confirmation light for each approach (4-way)
- Dual-color strobes for preemption approach (2-way)
- Single strobe light to indicate preemption is in operation. This option would indicate via one strobe beacon to both emergency responders and general public drivers that the intersection is operating in an extraordinary manner and to exercise caution.

The following criteria should be considered in the selection process:

- Safety of emergency vehicle operators
- Safety of general public
- Equipment and installation costs
- Maintenance

It is of note that there are safety concerns for an intersection where a single strobe confirmation light is in use with concurrent through phase indications given to both the approaching emergency vehicle and the opposing direction. Should multiple emergency vehicles be approaching from opposing directions, either driver may believe that he or she has the right of way to proceed through the intersection under preemption. The two vehicles may be in conflict when turning through the intersection.

Should the dual-color confirmation light be preferred through consensus, the discussion would also standardize the meaning of the different status and color of the confirmation light. The agreed upon solution would be approved and adopted through the MAG committee process so member agencies can move forward with the implementation of the solution. Once the confirmation light standard is adopted, any new optional installations of confirmation lights would be configured to the regional standards.

It is vitally important that agencies attending this workshop would include Fire and Police Departments for this discussion to gain their valuable input and viewpoints for this discussion. Any consensus for a solution would also necessitate an educational component to reach out to system users. In lieu of complete agreement, the “do-nothing” option will be exercised and there will be no change to the current practice, in which case an agency that opts to install confirmation lights for its EVP system would do so at its own discretion.

4.3 Regional EVP Coordination

For future consideration a regional EVP coordination forum could be established to facilitate the various functions regarding implementation and operations of the EVP systems across the MAG region. This regional EVP forum would be modeled after the East Valley EVP Working Group to include personnel from the fire department, ambulance services, traffic signal operations and maintenance, and traffic engineering for all regional members. The functions facilitated by the EVP coordination forum may include the following:

- Facilitate the technical discussions and selection of system compatibility solution and preemption treatments.
- Develop cost estimates for deployment of EVP technologies.
- Coordinate opportunities for joint procurement of EVP systems.
- Assist in the development and adoption of EVP standards and specifications in the Arizona Manual of Uniform Control Devices (MUTCD).
- Assist in developing Inter-Governmental Agreements (IGA) between member agencies for implementing system compatibility, preemption treatments, and other regional EVP solutions.
- Facilitate regional knowledge transfer regarding EVP deployment and operations. This could include the creation of a technical support team to assist in the design, procurement, installation, and configuration of EVP systems.
- Develop a regionally shared vision for future EVP purchases and deployment. This includes continuous evaluation of emerging EVP technologies concerning regional system migration and operational coordination. Develop a technology roadmap for implementing a regionally integrated EVP system. Establish a Memorandum of Understanding (MOU) detailing regional EVP vision, goals, and procurement and deployment practices.
- Identify Measures of Effectiveness (MOE) for monitoring regional EVP operations in support of emergency response automatic or mutual aid agreements. An example MOE includes the sharing and analysis of usage statistics (preemption events) in home and neighboring jurisdictions.
- Identify state-of-the-practice policies concerning liability and risk management that can be initiated in the Phoenix region.

Appendix A

CCMPO Policy Statement

CCMPO POLICY STATEMENT OF IMPLEMENTING A REGIONAL TRAFFIC SIGNAL PRE-EMPTION STANDARD

Regional coordination is necessary to ensure the effectiveness, security, and interoperability of traffic signal pre-emption systems in Chittenden County, in light of evolving needs and technologies.

Traffic signal pre-emption systems are currently used in several Chittenden County communities to expedite the movement of emergency vehicles through signalized intersections on the region's arterial roadways. These systems allow authorized emergency vehicles to override traffic signals using an optical emitter device mounted on the vehicle. Nationally, signal pre-emption equipment has been proven to reduce emergency response times, which in turn reduces fatalities and property destruction. In addition, these systems reduce the risk of collisions involving emergency vehicles at signalized intersections.

Existing traffic signal pre-emption systems in the County were installed by individual municipalities or the Vermont Agency of Transportation. This equipment uses an open industry standard that is increasingly obsolete and is subject to misuse by unauthorized individuals using illicit emitters to activate traffic signals.

Implementation of a regional, code-capable standard that is adopted and implemented by all affected parties will preserve the existing benefits of the existing, un-encodable system while providing numerous additional benefits:

- Greatly reduce the potential for misuse of the signal pre-emption system by unauthorized users;
- Allow for better tracking of system usage and performance; and
- Provide for future usage monitoring, data logging, and system maintenance.

Future signal preemption equipment installed in the region shall utilize the Strobecom II 2140 system, manufactured by Tomar Electronics Inc., or its comparable equivalent.

Implementation of a standardized code-capable system can occur in a phased manner, as existing traffic signal equipment reaches the end of its useful life, to minimize the cost of transitioning to an encoded system, or until an agreed-upon switchover deadline is reached.

The CCMPO recommends implementation of a near-term regional traffic signal pre-emption standard in Chittenden County to promote migration to a common technology platform. The regional standard should be endorsed by municipalities, emergency services, health care providers, the Chittenden County Transportation Authority, the Vermont Agency of Transportation, and other affected stakeholders in the region.

Adopted this 20th day of September, 2006 by the CCMPO Board of Directors.

Robert H. Penniman, Chair

Appendix B

Letter of Endorsement

HARRIS COUNTY EMERGENCY SERVICES DISTRICT NO. 11
c/o 820 Gessner, Suite 1710
Houston, Texas 77024

October 31, 2012
Lynn LeBouef, President

The Honorable R. Jack Cagle
Commissioner, Harris County Precinct 4
1001 Preston, Suite 950
Houston, Texas 77002

Dear Commissioner Cagle:

This letter is written on behalf of Harris County Emergency Services District No. 11 ("Harris County ESD 11").

As you may know, Harris County ESD 11 provides EMS to an area consisting of 250 square miles in the northwest/Spring area of Harris County. Harris County ESD 11 provides this EMS service through its service agreement with Cypress Creek EMS. (This service area overlaps the areas served by Ponderosa VFD, Spring VFD, Cypress Creek VFD, Champions FD, and Klein VFD, among others, who are first responders with Cypress Creek EMS.) To be sure our residents expect expeditious and professional emergency care which is what Harris County ESD 11, Cypress Creek EMS, and our fire departments are known for. However, as the population continues to grow our service area, new challenges arise which can hamper 911 emergency responses.

One daily challenge is the safe and rapid response in the ever increasing vehicle congestion along our roads and highways. Harris County ESD 11 supports the expansion of the EViEWS Emergency Vehicle Priority (EVP) System in Harris County. Harris County ESD 11 has worked with Harris County TranStar, Cypress Creek EMS, and our local fire departments on a multi-year evaluation of the EViEWS EVP System along the Louettta Road corridor. Travel time of the ambulances along this corridor has been significantly reduced following the implementation of the EViEWS EVP system, cutting lifesaving seconds. The program has proven so successful Harris County ESD 11 and our local fire departments were able to expand the project to TEXDOT/State roadways along FM 1960, FM 2920, and SH 249.

Faster response is not the only benefit of the EViEWS EVP System. Reduction of accidents involving emergency vehicles at Intersections as well as the rapid recovery of normal traffic patterns are highly sought benefits of the fire/EMS community as well as Harris County TranStar. Harris County ESD 11 therefore requests the Harris County Commissioner's Court to approve the EViEWS EVP System final report and allow further expansion of this system along Harris County roadways. Harris County ESD 11 is ready to continue its part of the funding of this project along with the area fire ESDs under an Interlocal Agreement similar to the current program that has worked so well.

Sincerely,

Lynn LeBouef
President

Appendix C

Harris County Emergency Vehicle Priority System Requirements - Local Controller Firmware

Harris County Emergency Vehicle Priority System Requirements

Local Controller Firmware

Objective: To serve emergency vehicle(s) with minimal disruption to vehicular traffic

Traffic Signal Firmware Requirements:

- The natural controller sequence shall be preserved at all times. By default no phases are skipped and left-turn signals operate as normal unless requested by the emergency vehicle
- No phase with demand shall be shortened to less than the alternate minimum green and the priority shall proportionally truncate all conflicting phases subject to this constraint
- In the instance where phase truncation is necessary (with full vehicular demand on the conflicting movements), the controller shall not arrive on the service phase earlier than the specified travel time for that approach
- The firmware shall have at least 4 emergency vehicle priority modules (one per direction)
- Each module should consist of the following programming items:
    - Primary service phase (thru phase) – activated by GPS advance message(s)
    - Secondary service phase (left-turn phase) – activated by GPS left-turn message
    - Flags with the ability to omit phases or pedestrian movements as necessary for each of the priority modules (no omits by default)
    - Travel time parameter for the primary service phase (thru-phase) where the specified movement shall be green by the time the vehicle is that distance away
        - Any conflicting walk rest shall be terminated once a conflicting emergency vehicle request is recognized by the controller
        - On a coordinated street the opposing direction walk rest shall be terminated only if a conflicting secondary service phase is programmed
        - Any walk rest parallel to the emergency vehicle shall rest as normal
    - Travel time parameter for the secondary service phase (left-turn-phase) where the specified movement shall be green by the time the vehicle is that distance away
    - Check out input – activated by GPS check-out message
    - Maximum presence timer where the priority is ignored until the call is dropped
- A conflicting emergency vehicle priority request on the cross street shall be able to force-off the coordinated phases early in order to serve the green by the specified travel time
- The controller firmware shall have mechanism in place to prevent acceptance of increasing travel times from the GPS unit if the emergency vehicle were to encounter reduced speeds
- All phases shall have an alternate priority minimum green (typically greater than the normal minimum green) that will apply if there is demand for a particular phase. This prevents the short timing of phases if short-way transition is required
- Upon check-out the controller shall immediately move onto the next phase if the priority is timing beyond the normal force-off point, subject to the alternate minimum green
- All priority requests and left-turn requests, including Vehicle ID shall be logged by the controller and be brought back to the ATMS (central system) for further analysis

Appendix D

Harris County Emergency Vehicle Priority System Requirements - GPS System

Harris County Emergency Vehicle Priority System Requirements GPS System

Objective: To serve emergency vehicle(s) with minimal disruption to vehicular traffic

GPS System Requirements:

GPS shall report the following to the traffic signal controller for <u>each</u> approach (4 minimum):

- Travel Time away from the intersection (in seconds)
- Minimum 80 seconds advance notice is required
- Travel time must be passed directly to the controller via Ethernet (using a crossover cable if no Ethernet switch is present) and pass the Vehicle ID directly to the controller
- Vehicle ID shall visible from the controller front panel and in the controller logs
    - In no instance shall raw inputs in the detector racks be used
    - A minimum of 4 messages <u>per direction</u> via Ethernet (16 total) are required
        - 2 advance messages (4 preferred)
        - 1 left-turn message (latched)
        - 1 check-out message (active when vehicle is at the stop-bar)
    - Each of the advance messages shall not activate until the specified travel time away from the intersection is reached
- GPS unit shall pass along left-turn requests (default is no left-turn)
    - Left-turn request is provided via Ethernet and must be logged
        - This message is passed along on an intersection by intersection basis
        - The left-turn request is only valid for the next intersection after passing the previous intersection
    - Left-turn inputs are a “latched” call linked to the vehicle left-turn signal
        - Left-turn signal shall only need to be on for a second to latch
        - Left-turn must not latch to more than one intersection at a time
        - Left-turn request shall be remembered after passing the previous intersection but have the ability not to pass the call to the controller until the emergency vehicle is the specified travel time away from the intersection
- GPS unit shall have mechanism in place to prevent sending increasing travel times to the local intersection controller
- GPS unit shall send a check-out request to all downstream intersections (provided there are no other active emergency vehicles on that approach) if the vehicle is in park or there is a communication loss between the vehicle and the controller (in seconds)
    - A vehicle in park shall immediately send the check-out request to the controller pending no other active priority requests on that approach
    - GPS shall have a separate time-out value (in seconds) for communication loss configurable on a per approach basis

Appendix E

Court order for executing Inter Governmental Agreement for deploying the EVP

ORDER OF COMMISSIONERS COURT
Authorizing an Interlocal Agreement for the Deployment of an
Emergency Vehicle Priority System

The Commissioners Court of Harris County, Texas, met in regular session at its regular term at the Harris County Administration Building in the City of Houston, Texas, on __________________________, with all members present except ________________________________.

A quorum was present. Among other business, the following was transacted:

ORDER AUTHORIZING EXECUTION OF AN INTERLOCAL AGREEMENT BETWEEN HARRIS COUNTY AND THE CITY OF WEBSTER IN REGARDS TO DEPLOYMENT OF AN EMERGENCY VEHICLE PRIORITY SYSTEM ON COUNTY ROADS WITHIN THE CITY OF WEBSTER FIRE DEPARTMENT'S SERVICE AREA

Commissioner ______________________ introduced an order and moved that Commissioners Court adopt the order. Commissioner ______________________ seconded the motion for adoption of the order. The motion, carrying with it the adoption of the order, prevailed by the following vote:

	Yes	No	Abstain
Judge Ed Emmett	☐	☐	☐
Comm. El Franco Lee	☐	☐	☐
Comm. Jack Morman	☐	☐	☐
Comm. Steve Radack	☐	☐	☐
Comm. R. Jack Cagle	☐	☐	☐

The County Judge thereupon announced that the motion had duly and lawfully carried and that the order had been duly and lawfully adopted. The order thus adopted follows:

IT IS ORDERED THAT:

1. The Harris County Judge is authorized to execute on behalf of Harris County an Interlocal Agreement between Harris County and the City of Webster in regards to deployment of an emergency vehicle priority system on County roads within the City of Webster Fire Department's service area. The County is not obligated to expend any funds pursuant to the Interlocal Agreement. The Interlocal Agreement is incorporated by reference and made a part of this order for all intents and purposes as though fully set forth word for word.

2. All Harris County officials and employees are authorized to do any and all things necessary or convenient to accomplish the purposes of this order.