Guidelines for the Planning and Deployment of Emergency Vehicle Preemption and Transit Priority Strategies

Prepared as part of a Research Project
Conducted by
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and
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January 2006

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Preface

Emergency vehicle preemption and transit priority are two forms of preferential traffic signal control strategies provided to facilitate the flow and passage of fire and rescue vehicles and transit buses. Transit priority requests are often conditional and may, for example, be granted on one or more conditions such as the absence of a pedestrian phase, the presence of a green interval, and a prescribed level of bus occupancy or degree of bus lateness. Emergency vehicle preemption requests, on the other hand, are usually only conditional on the absence (or completion) of the pedestrian phase and may involve either a green extension or a red truncation. A trend taking place is to coordinate the planning and deployment of emergency vehicle preemption and transit priority strategies for the purposes of developing a single, integrated traffic signal control system.

This document provides guidelines on the planning and deployment of emergency vehicle preemption and transit priority strategies and should be of interest to state and local traffic engineers, fire and rescue officials, and public transit planners and operators in the Metropolitan Washington D.C. Region.

This document is a product of a research project underway at the Virginia Tech Transportation Institute (VTTI) in collaboration with George Mason University. The project entitled, *A Study to Examine the Use of Signal Preemption and Other Priority Strategies along Signalized Intersections in the Washington, D.C. Area*, began in March 2000.

The sponsors of this research are the Washington Metropolitan Council of Governments, Virginia Department of Transportation, and the Maryland Department of Transportation.

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Section 1: Planning

1.1 Institutional Issues, Local Needs Assessment, and System Objectives and Requirements.

Planning for an emergency vehicle preemption (EVP) and transit priority (TP) system is not a trivial task. A variety of institutional issues and local concerns must be addressed ranging from the identification of the important stakeholders, to the assessment of local EVP and TP system needs and the formulation of local EVP and TP system objectives and requirements (Gifford, Pelletiere, and Collura, 2001). To guide traffic, transit, and emergency response professionals in EVP & TP system planning, Exhibit 1 provides a structured approach to aid in addressing institutional issues and needs and in turn to facilitate the development of system objectives and requirements.

1.2 Pre-Deployment Impact Analysis

As part of planning, stakeholders should conduct a local impact analysis to assess the anticipated consequences of alternative EVP and TP strategies under consideration. Among those consequences may be the impact on traffic flow and vehicular and pedestrian safety. This local impact analysis may include site-specific surveys, empirical analyses and the use of microscopic simulation modeling tools such as CORSIM, INTEGRATION, VISSIM, PARAMICS, and MITSIM, which attempt to model the behavior of individual vehicles (Fujimoto & Leonard, 2001; Chang, Rahka, Dion, and Collura, 2003).

Based on a review of literature as part of this research project, the impacts of EVP and TP have been both positive and negative in more than a dozen actual EVP and TP project deployments in the U.S. and abroad. Moreover, simulation analyses reported in the literature review have produced results generally consistent with the impacts actually experienced in the project deployments. An overall observation made based on the literature review and the field tests conducted as part of this research project to date is that EVP and TP strategies can be integrated into conventional traffic signal control systems in an appropriate and desirable manner, provided that such integration is done with caution, that anticipated impacts are considered, and that the EVP and TP system and equipment are designed and installed properly.

Traffic Flow

There is some evidence that the implementation of emergency vehicle preemption and transit priority strategies may reduce travel times for emergency vehicles and transit vehicles. However, another expected impact may be delay to all other vehicles. To illustrate the level of magnitude of these impacts, a summary of past and on-going research on emergency vehicle preemption and bus priority is provided below.

Emergency Vehicle Preemption

EVP systems have been widely deployed in the U.S. The experiences of some agencies operating these systems indicate that significant improvements to average EV travel time may result (Collura, Chang, Willhaus, Gifford, 2000). For example, Denver, Colorado reported EV response time decreases of 14-23% (City of Denver, 1978); Addison, Texas claimed a 50% decrease in response time (BRW, 1997); and Houston, Texas indicated an average improvement in travel time of 16-23% (Traffic Engineers, Inc., 1991).

While there is limited empirical data on the impact of EVP on overall traffic flow, researchers have found using simulation models that travel time impacts of EVP depends on the intersection spacing, transitioning algorithm, saturation of the intersection, frequency and duration of the preemption, and the amount of slack time available in each intersection. For example, it was found using simulation analyses that a preemption event would increase non-EV vehicle delay by less than 3% along Route 7 in Northern Virginia (Bullock, Morales, and Sanderson, 1999); however, multiple preemption events over a short period of time would cause significant delay to the network (Nelson and Bullock, 2000). Recovery from the preemption event depends on the duration of the preemption, recovery strategy, and traffic conditions. For example, in a high volume environment, it was found using simulation models that the network travel time would taper over time from around 12.2% over normal fifteen minutes after preemption to around 3%, over normal sixty minutes after the preemption event (McHale and Collura, 2001). While these results are dependent on the prevailing geometric and operational conditions, they provide an "order of magnitude" estimate for the impact of preemption. Exhibit 2 illustrates a typical network response to preemption on travel time delays over a 1-3 hour interval in low, medium and high volume environments.

Empirically based analysis may also be used to assess the traffic flow impact of EVP. For example, the Highway Capacity Software (HCS) intersection Level of Service (LOS) functionality can be used to examine the impact of various recovery strategies using side street queue data (Collura, Mittal, and Louisell 2002). It is important to point out that the impact of signal preemption on side street traffic will be related to several factors including the frequency, as well as, the average duration of preemption requests. In general, the lower the frequency and the lower the duration of preemption requests, the less the impact on side street traffic. For example, the average queue length on a side street with a volume of approximately 130 vehicles per hour along a section of U.S. 1 was equal to 9 vehicles per cycle. It should be noted that the average duration of preemption requests along this section of Route 1 was 16 seconds. Exhibit 3 provides supplemental information on the frequency of EVP requests along U.S.

1. It can be observed from Exhibit 3 that the frequency of EVP requests on average is less than one per hour and that the variation in this average is reflected in the corresponding standard deviations provided in parentheses.

Transit Priority

Most transit priority projects have only been deployed in the U.S. within the past few years and results from operational field test evaluations and simulation analyses are difficult to compare across the board because performance measures are not well defined in a standardized framework. Moreover, different TP strategies including green extension only and green extension in combination with red truncation and other tactics yield different impacts. Experience from a number of transit priority projects in the U.S. and abroad suggests that transit priority may, depending on the TP strategy employed and other factors, reduce transit travel times 6 to 42% with little or no negative impacts on non-transit travel time, if properly deployed. (Chang, Overview, 2002; Soo, H., Collura, J., Teodorovic, D., and Tignor, S.). Exhibit 4 summarizes the results of transit priority projects in the U.S. and other countries.

It should also be stressed that traffic simulation models may be a cost effective means to analyze the impact of transit priority on traffic flow. As part of this research project, the INTEGRATION simulation model was used on Columbia Pike in Arlington County to assess impacts of a green extension only strategy on both transit and non-transit vehicles. Results indicated that bus service reliability improved by 3.2%, run time decreased by 0.9% and non-transit vehicle delay increased by 1.0% (Chang, Collura, Rakha, and Dion, 2003).

Also as part of this research project, the VISSIM simulation tool was used to assess the impact of a green extension only priority strategy along a section of U.S. Route 1, a high volume urban arterial in Northern Virginia. Initial results, shown in Exhibit 5, indicate that transit travel time with priority, on the average, is less than transit travel time without priority and that the impact on non transit traffic is small (Deshpande, Collura, Teodorovic, and Tignor, 2003).

It should also be pointed out that the transit priority strategy might have a varying level of impact on transit and other vehicles. As illustrated in Exhibit 6, a green time extension in general, provides constant benefit to buses with no travel time impact to other users (Hounsell, 1998). However, green extension in combination with red truncation (i.e. recall) may negatively impact non-transit vehicles, depending on the frequency of bus service. It is further recommended that a TP strategy consider the specific conditions that influence the corridor of interest. These conditions may include: frequency and direction of travel for vehicles requesting priority, roadway characteristics, travel demand, presence and frequency of pedestrian phases, transition strategy, cycle characteristics, and intersection spacing and progression strategy (Obenberger and Collura, 2002). The use of different types of priority control such as queue jumping and phase reservicing in addition to green extension may be necessary to match the status of the intersection in order not to affect signal coordination (Hood, Hicks, and Singer, 1995).

Safety

Emergency Vehicle Preemption

In the seven-year period from 1994-2000, more than some 643 EV crashes involving one or more fatalities occurred nation-wide (USDOT, 2002). There is evidence to suggest that the deployment of EV preemption may decrease the number and severity of accidents involving EVs and other vehicles at signalized intersections. St. Paul, Minnesota reported an accident rate reduction of greater than 70% between 1969 and 1976 when it installed 285 signal preemption systems on 308 signalized intersections (St Paul, 1977). Since the national data supports the notion that EV safety is a critical issue, local stakeholders may want to examine the potential impact of EVP on safety at one or more areas under study.

A major product of this research project is the development of an analytical tool to investigate the potential for accidents between EVs and non-EVs at critical intersections. This tool applies the techniques of Conflict Point Analysis, an analytical approach used by the traffic engineering and safety community, to examine the likelihood that accidents may occur (Garber and Hoel, 1999). An illustrative example of this methodology is provided in Exhibit 7. The potential for accidents can then be determined using a set of logic rules for the type of conflict, the number of vehicles in each conflict stream, speed of the vehicles in the stream, and the degree of the situational understanding on the part of the drivers. Results of an analysis using this tool are presented in Exhibit 8.

Pedestrians

Pedestrian accidents with motor vehicles represent a serious safety problem. Pedestrian fatalities account for approximately 12.6% of the motor vehicle deaths nationwide. In terms of accident locations, 35% of accidents involving pedestrians occur at intersections (Zegeer and Seiderman). It is suggested that a safety audit be conducted during the planning of EVP & TP systems. This audit should review the potential impacts EVP and TP strategies might have on pedestrian safety. This audit should review the historical accident data within the area of interest; the length of pedestrian cycles based on the age and other demographics of the local population; the location of residential housing and retail activities; location and placements of bus stops; pull off areas; and distance between bus stop locations.

1.3 Economic Analysis

It is strongly recommended that an economic analysis be performed prior to EVP and TP deployment to identify and estimate the fixed and recurring costs associated with EVP and TP investments. As shown in Exhibit 9, ITS projects, such as EVP and TP may typically have a short service life, lower upfront investment costs, and higher operating costs than traditional physical infrastructure projects. Since the cash flow profile of ITS and traditional investments are radically different and the time value of money for ITS investments may not be that important, it has been argued that traditional benefit-cost analysis may not be appropriate and a multi criteria analysis approach should be used (Leviakangas and Lahesmaa, 2002). It is suggested that life cycle cost analysis be employed and an attempt be made to look at all life cycle capital and operational costs within a larger economic analysis framework.

1.4 Financing

A financial plan for EVP and TP system deployment needs to be developed. This plan will identify funding sources to support capital investments and to defray operating and maintenance costs. Funding is available from Federal, state, and local sources such as Congestion Management and Air Quality (CMQP) and other programs in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA-91). It should also be stressed that such public funding sources may include transportation agencies as well as local fire and rescue departments.

Section 2: Deployment

2.1 Procurement

While it has been suggested that EVP and TP systems can be procured using standard procurement processes, there are special considerations that need to be taken into account. Lessons learned from past ITS procurements and procurement experiences on the U.S. 1 operational field test in Northern Virginia were used to provide insights into the identification of system objectives and requirements and preparation of requests for proposals and proposal evaluation.

Identification of Systems Objectives and Requirements

The procurement process begins with the identification of project objectives and requirements. As mentioned in section 1.1 of these guidelines, a clear understanding of the project scope of work is required of all stakeholders and participants to manage expectations and to preclude misunderstanding later in the process. Technological limitations must also be understood. A common frame of reference and a common definition of terms will need to be developed and adhered to. The proposed system objectives and requirements will then be translated into technical and operational requirements for venders to develop into a fully functional system. Sound technical specifications are a prerequisite for success. Vaguely defined requirements will result in confusion and will necessitate negotiation with the contractor to settle differences.

RFP Preparation/Proposal Evaluation

A Request for Proposals (RFP) defines the project scope of work and system objectives and requirements, provides the technical and operational performance requirements, outlines the compliance requirements, and defines the performance period. It is suggested that a single integrator be responsible for design, procurement of components, system integration, installation, testing of the project, and user training. This allows the user to provide oversight of the process. Exhibit 10 includes an example of an RFP used to deploy an EVP and TP system on U.S. 1 in Northern Virginia and offers an example of the important elements to be included in a RFP.

2.2 Pre-Installation Site Survey

A pre-installation survey by the contractor(s) is highly recommended. As part of this on-site survey, the contractor should determine the impact of roadway geometry, bus stop placements, line of sight restrictions, pedestrian crossing volumes, and existing equipment to the system design. For example, in the case of installing equipment for EVP in areas that have closely spaced signalized intersections, it is important to consider the effect of overlapping detection distances. In the case of bus priority, detector placement must be carefully sited to avoid putting a bus in the dilemma-zone when the traffic signal turns amber. Detector placement and installation will need to consider the impacts of bus speed, length of green extension, and intersection width as well as location of bus stops. For example, for a bus traveling at 15 mph (22 fps) with a maximum green extension of 10 seconds through an intersection width of 40 feet, a detection distance of approximately 180 feet provides sufficient time to allow the bus to clear the dilemma zone.

2.3. System Installation

The typical EVP and TP system has three major subsystem components, including the in-vehicle subsystems, road-side subsystems, and center subsystems. Each subsystem has its own installation challenges. **In-vehicle subsystems** consist of those component parts of the system that are installed on the vehicle. For example, a simple EVP and TP system may consist of the emitter, its power system and its microprocessor system. More complex systems may include a vehicle location device such as a GPS locator and automatic passenger counters. **Road-side subsystems** are those parts of the system that reside outside the designated vehicles. Typically, they would include detectors mounted in the vicinity of the traffic signals and power sources that service the detectors, microprocessors and communications equipment collocated with the traffic signal controller boxes. **Center subsystems** are those items of equipment that must interface with the central traffic signal management system, the transit management system, and home station monitoring systems.

It is recommended that the contractor be responsible for quality control throughout the installation process. The contractor should be required to provide installation drawings for approval. In addition, the contractor should be required to present a prototype installation of every subsystem and complete operational testing of all prototype installations. The contractor should also provide for review site-specific installation specifications tailored to the physical characteristics of each site.

2.4. Evaluation

System evaluations during deployment provide a means to assess whether an EVP and TP system meets its intended objectives. The evaluation process should consist of the following elements: (1) an evaluation frame of reference, (2) evaluation planning, (3) evaluation implementation, and (4) potential evaluation spin-offs (Casey and Collura, 1994). Exhibit 11 presents a flow diagram depicting such an evaluation process.

The evaluation frame of reference provides a context for the evaluation. It defines the project objectives, external influences, local issues, and site characteristics. The evaluation plan outlines what should be measured (the impacts) and how impacts might be measured (measurement criteria). Evaluation implementation outlines evaluation plan execution, data collection, and analysis. For additional guidance on the design of ITS project evaluations, see the U.S. DOT's Joint Program Office website (USDOT, 2003).

A major product of the evaluation is an assessment of system objectives and impacts, including benefits, costs, and other consequences. For example, EVP performance measures may relate to emergency vehicle crash potential, emergency vehicle delay, and impact to other vehicles. Data elements and potential sources of information for these measures are illustrated in Exhibit 12 (Louisell, Collura, and Tignor, 2003). Transit priority system objectives may relate to transit service reliability, efficiency and other traffic impacts. Exhibit 13 presents examples of transit priority objectives and corresponding measures (Chang, Collura, Rakha, and Dion, 2002). In addition, the EVP and TP system evaluation should assess broader impacts related to interoperability, maintainability, reliability, expandability, affordability, institutional and organizational issues, and human factors.

Finally, it should be stressed that evaluations should be conducted as soon as possible during deployment. As shown in Exhibit 14, over 90% of the agencies that have deployed EVP strategies have not performed evaluations (Asmussen et al, 1997). Evaluations provide a means to measure the performance of the system against measurable criteria and the results supply agencies in other metropolitan areas with useful information regarding deployment results, challenges, and lessons learned.

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LIST OF EXHIBITS

Exhibit 1: Identification of Institutional Issues, System Objectives, and System Requirements.

This exhibit is intended to evaluate whether an emergency vehicle preemption or transit priority system will meet the concerns, objectives and requirements of stakeholders. An underlying aim of this exhibit is to aid in the identification of important institutional questions and issues that might be raised by stakeholders so that you can enter the planning process better prepared to articulate system objectives and requirements.

In Section A, answer only the sections that apply to the EVP and TP system you are considering.

Section A: System Objectives

Guidelines for EVP:

1) Do you feel comfortable that you will be able to show stakeholders - elected officials, residents, and other agencies - that one or more of the following objectives will be met by installing the EVP system you have chosen?

Preemption Objective 1: The EVP system shall reduce the average response time for emergency vehicles to respond to incidents.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

Preemption Objective 2: The EVP system shall have a positive impact on the health and safety of emergency personnel.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

Preemption Objective 3: The EVP system shall reduce the frequency of crashes involving non-emergency vehicles related to the disruption caused by responding emergency vehicles (that is, either crashes between responding units and non-emergency vehicles, or between non-emergency vehicles attempting to avoid or make way for responding emergency units).

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

1a) Based on the answers above

If you answered **YES** to more than one of the above, it is advisable for you to present the preemption system you have chosen to stakeholders once you have determined you can answer the remaining questions in this section.	If you answered **NO** to more than one of the above or if the system is not intended to achieve these objectives, you may need to reconsider whether you can justify implementation or if you need more information; it is suggested that you continue with these questions to see what further information will be needed.

Guidelines for TP:

1) Do you feel comfortable that you will be able to show stakeholders - elected officials, residents, and other agencies - that one or more of the following objectives will be met by installing the TP system you have chosen?

Priority Objective 1: The TP system shall improve schedule adherence.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

Priority Objective 2: The TP system shall improve bus efficiency, reducing bus operating costs and allows greater schedule flexibility.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

Priority Objective 3: The TP priority system shall be part of a larger Intelligent Transportation System (ITS) application, such as a traveler information service.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

Priority Objective 4: The TS system shall improve the overall efficiency with which the road network is used.

◇ Yes, I have enough information to show this is true for the system we have chosen.	◇ No, because the system is not expected to achieve this objective. ◇ No, I need more information.

1a) Based on the answers above

If you answered **YES** to more than two of the above, it is advisable for you to present the TP system you have chosen to stakeholders once you have determined you can answer the questions in section B.	If you answered **NO** to more than two of the above or if the system is not intended to achieve these objectives, please reconsider whether you can justify implementation or if you need more information; it is suggested that you continue with these questions to see what further information will be needed.

Section B: System Requirements

System requirements for EVP and TP fall into the following major categories: accountability, interoperability, flexibility/adaptability, maintainability, and control of operations. This section should be completed first for EVP and then a second time for TP, on the assumption that both EVP and TP will co-exist in a single system. If only EVP is being considered and TP is not of interest (or vice versa), then this section only needs to be completed once for the preferential signal strategy being considered.

Accountability

Some system planners and implementers claim that system users should be held accountable for their use of the system.

1) Will a detailed record be kept and easily accessible that could be used to determine which specific individual or vehicle triggered the system in a specific instance?

◇Yes	◇ No

2) Will there be technical “interlocks” that will determine whether the system can be used (e.g. linking use of the system to emergency backup plans)?

◇Yes (Can you list specific interlocks that will be used?)	◇No

3) Do you have a clear written or proposed policy on WHO can use the system (e.g if EVP is being considered, do only fire and EMS personnel have the authority to use the system, and in the case of TP do only selected routes at certain times of day have the authority to use the system)

◇Yes	◇ No

4) Do you have a clear written policy or proposed policy on under what situations the system can be triggered)?

◇Yes	◇ No

5) Do you have a clear written policy or proposed policy governing installation of the system at a specific intersection?

◇Yes	◇ No

NOTE: It is not always appropriate to have these policies in place prior to approaching stakeholders, however, if you have answered NO to any of the above some thought should be given to these matters before approaching other stakeholders.

Interoperability

Interoperability is often an issue when one or more jurisdictions or agencies anticipate working together.

1) Have you contacted all jurisdictions with which you work closely about installing this system?

◇Yes	◇ No

2) Are similar systems in use or planned in these other jurisdictions?

◇Yes If yes, proceed to the next question.	◇ No If no, please proceed to question 5.

3) Will the system you are installing be interoperable with those used or planned in these other jurisdictions?

◇Yes Be sure to mention this in meetings with other stakeholders.	◇ No If no, are you comfortable with this lack of interoperability? Take a closer look at how you might achieve interoperability.

Flexibility/Adaptability

1) Once the system is installed, in your judgment is it possible to easily add, remove or move the equipment from a single location?

◇Yes Be sure to mention this in meetings with other stakeholders.	◇ No If no, are you comfortable with this lack of flexibility?

2) Once the system is installed, in your judgment is it possible to adjust the system on an intersection-by-intersection basis?

◇Yes Be sure to mention this in meetings with other stakeholders.	◇ No If no, are you comfortable with this lack of flexibility?

3) Once the system is installed, in your judgment is it possible to adjust or alter the operation of the system remotely without having to access the equipment at individual intersections?

◇Yes Be sure to mention this in meetings with other stakeholders.	◇ No If no, are you comfortable with this lack of flexibility?

If you answered no to more than one of these questions you may meet resistance from stakeholders, particularly elected officials. You may want to work with the chosen vendor or another vendor to resolve the matter.

Maintainability

1) Are you comfortable with the ease of maintenance for the system you may choose?

◇Yes Continue with the rest of the questions in this section.	◇ No Take whatever steps you feel are necessary to allay your concerns. Continue with section 7 below.

2) Have you spoken to other jurisdictions who have installed this system about their experiences with maintenance and you are satisfied with their responses?

◇Yes	◇ No

3) Do you have any estimates or contractual amounts for the cost of replacement equipment or specialized services that may be required?

◇Yes	◇ No

If you have answered YES to all three questions, you should have enough information to approach other stakeholders.

Control of Operations

Stakeholders are often concerned about who has responsibility for the system once it is installed in the field and that this division of responsibility is clear and unambiguous.

1) Have you determined or is it clear to you who will decide where and how the system will be installed, operated, and maintained?

◇Yes Continue with the next question in this section.	◇ No You may want to work on some suggestions of how this should be done and revisit the second question in this section.

2) Will it be your department or another department or agency that in your view will make this decision?

◇ My department or agency Have you discussed this sufficiently both within you group and with other stakeholders? ◇ Yes ◇ No If NO, is this likely to be a problem?	◇ Another department or agency Have you clarified this with the outside entity you see doing the maintenance? ◇ Yes ◇ No If NO, is this likely to be a problem?

3) Are you comfortable with how the operator of the vehicle will have to interact with this system?

◇Yes Be sure to be clear on why you think this issue will not be a problem with the system you have chosen.	◇ No Work with the chosen vendor or another vendor to achieve a preferred level of operator/system interaction.

Again, it should be stressed that this questionnaire is intended to raise important questions about the institutional aspects of the system you are considering to deploy before you approach stakeholders with proposed EVP and TP system alternatives. The questionnaire is not an examination of the likelihood of success of the system, nor does the questionnaire contain an exhaustive list of all potential institutional concerns and questions. Unique local conditions may result in concerns and issues not reflected in the questionnaire, and thus may require system planners and implementers to consider other factors in the identification of system objectives and requirements.

Exhibit 2: Travel Time Impacts of Emergency Vehicles Preemption on Travelers

Percent Difference in Travel Time for All Travelers (Assuming One EV and One Preemption Event per Analysis Period)				
	Typical Level of Congestion			
Type of Approach	Analysis Period (hours)	Low	Medium	High
Main Street Non Preemption Path	1	1.10%	2.40%	3.30%
	2	0.60%	1.00%	1.70%
	3	0.00%	0.00%	0.00%
Uncongested Side Street Non Preemption Path	1	1.30%	1.90%	2.00%
	2	0.70%	1.00%	1.00%
	3	0.00%	0.00%	0.00%

Source: McHale, G. and Collura, J., Improving the Emergency Vehicle Signal Priority Methodology in the ITS Deployment Analysis System (IDAS), proceedings of ITS World Congress, Sydney, 2001.

Exhibit 3: Frequency of Emergency Vehicle Preemption Requests US 1 Operational Test Site

Intersection	*Emergency Vehicle Preemption Requests During the AM Peak Period (6:00 AM-9:00AM)**					
	Mean/3 hr period		*Mean/hr*		*Minimum*	*Maximum*
RT.1 & Popkins Lane	0.30	(0.67)	0.10	(0.22)	0	3
RT.1 & Memorial St.	0.30	(0.70)	0.10	(0.23)	0	3
RT.1 & Beacon Hill Rd.	0.28	(0.66)	0.09	(0.22)	0	3
RT.1 & Southgate Dr.	1.15	(1.36)	0.38	(0.45)	0	5
RT.1 & South Kings Hwy	0.77	(1.22)	0.26	(0.41)	0	4
RT.1 & North Kings Hwy	0.83	(1.64)	0.28	(0.55)	0	10

Intersection	*Emergency Vehicle Preemption Requests During the PM Peak Period (16:00PM-19:00PM)**					
	Mean/3 hr period		*Mean/hr*		*Minimum*	*Maximum*
RT.1 & Popkins Lane	0.94	(1.39)	0.31	(0.46)	0	6
RT.1 & Memorial St.	1.25	(1.59)	0.42	(0.53)	0	7
RT.1 & Beacon Hill Rd.	1.25	(1.47)	0.42	(0.49)	0	7
RT.1 & Southgate Dr.	1.30	(1.79)	0.43	(0.60)	0	4
RT.1 & South Kings Hwy	1.30	(1.31)	0.43	(0.44)	0	4
RT.1 & North Kings Hwy	1.32	(1.45)	0.44	(0.48)	0	7

Intersection	*Emergency Vehicle Preemption Requests During Midday (9:00AM-16:00PM)**					
	Mean/7 hr period		*Mean/hr*		*Minimum*	*Maximum*
RT.1 & Popkins Lane	2.02	(1.79)	0.29	(0.26)	0	7
RT.1 & Memorial St.	2.55	(2.02)	0.36	(0.29)	0	9
RT.1 & Beacon Hill Rd.	5.08	(1.70)	0.73	(0.24)	0	7
RT.1 & Southgate Dr.	3.89	(2.15)	0.56	(0.31)	0	9
RT.1 & South Kings Hwy	2.83	(2.23)	0.40	(0.32)	0	9
RT.1 & North Kings Hwy	2.66	(2.41)	0.38	(0.34)	0	10

Intersection	*Emergency Vehicle Preemption Requests During Night (19:00PM-6:00AM)**					
	Mean/11 hr period		*Mean/hr*		*Minimum*	*Maximum*
RT.1 & Popkins Lane	2.85	(2.37)	0.26	(0.22)	0	9
RT.1 & Memorial St.	2.85	(2.13)	0.26	(0.19)	0	9
RT.1 & Beacon Hill Rd.	2.53	(2.32)	0.23	(0.21)	0	7
RT.1 & Southgate Dr.	4.72	(2.87)	0.43	(0.26)	0	12
RT.1 & South Kings Hwy	3.55	(2.76)	0.32	(0.25)	0	10
RT.1 & North Kings Hwy	3.45	(2.66)	0.31	(0.24)	0	11

** Emergency Vehicle preemption request data represents a 53 day period from July 16, 2002 to September 6, 2002. Values in parentheses are the standard deviations.*

Source*:* Data collected for the scope of this research project with the use of the 3M Opticom System (7/16/2002-9/6/2002).

Exhibit 4: Results of Transit Priority Projects in U.S. and Other Countries

U.S. Experiences ***Simulation Studies***	**Measure**	**Result**
Fairfax, VA - U.S.1 VISSIM [(1)]	Bus Travel Time	2.64 % decrease
	Time Reliability	3.61 % improvement
	Average Queue Length on Side Street	1.28 ft increase (less than one car length) Not significant
Arlington, VA Columbia Pike Blvd INTEGRATION [(2)]	Bus Travel Time	0.9 % decrease
	Arrival Reliability	3.2 % improvement
	Overall Vehicle-Delay	1 % increase
Arlington, VA Columbia Pike Blvd SCOOT/INTEGRATION [(3)]	Bus Travel Time	6% decrease
	Overall Person-Delay	8% increase
Bremerton, WA [(4)]	Bus Travel Time	10% decrease
	Stopped Delay/Vehicle	Not significant
Baltimore, MD TRANSYT [(5)]	Light Rail Operating Speeds	7% decrease
	Individual Vehicle Delay	14% increase
Seattle, WA TRAF-NETSIM [(6)]	Bus Delay	33% decrease
	Impacts to private vehicles	Minimal
Washington, District of Columbia UTCS-1 [(7)]	Bus Travel Time	22 to 32% decrease
	Cross Street Traffic Travel Time	6 to 30% increase *(far-side stops)* 9 to 66% increase *(near-side stops)*
Ann Arbor, Michigan NETSIM/TRANSYT-7F[(8)]	Bus Travel Time	6% decrease *(for a single bus)*
Austin, Texas NETSIM [(9)]	Bus Travel Time	11% decrease *(optimized lower cycle length)* 10% decrease *(phase splitting)*
Chicago, ILL TRAF-NETSIM /TRANSYT-7F [(10)]	Bus Travel Speed	24% increase
	Bus Travel Time	30% decrease

(Exhibit 4 continues to the next page)

U.S. Experiences *Field Studies*	Measure	Result
Portland, OR (2002) Tri-Met BDS/AVL Line 12 Barbur [11]	Median Run Time	Up to 3 minute-decrease *(before and after analyses one year apart*)
	Coefficient of Variation *(measure of run time & schedule reliability)*	Up to 3.5% decline *(before and after analyses one year apart)*
Portland, OR (2002) Tri-Met BDS/AVL Route 4 Fessenden [11]	Median Run Time	Up to 46 second-decrease *(before and after analyses two months apart)*
	Coefficient of Variation *(measure of run time & schedule reliability)*	Up to 7% decline *(before and after analyses two months apart)*
Charlotte, NC / Opticom (Express Buses) [12,13]	Bus Travel Time	4 minute decrease
	Cross Street Delays	Not unacceptable
Portland, OR Powell Bvd TOTE & LoopComm Tests [14,15]	Bus Travel Time	5 to 8% decrease
	Vehicle or Person Delay	Not significant
Portland, OR Tualatin Valley Highway [16]	Bus Travel Time	1.4 to 6.4% decrease
	Bus Signal Delay	20% decrease
Portland, OR Pilot Routes [17]	Bus Travel Time	10% decrease
	On Time Performance	8 to 10% improvement
Chicago, IL Cermak Road [18]	Bus Travel Time	7 to 20% decrease, depending on time of day, travel direction
	Cross Street Delays	8.2 seconds/vehicle
Minneapolis, MN Louisiana Ave Opticom [19]	Bus Travel Time	38% decrease *(High priority)* No change *(Medium or Low priority)*
	Auto Stopped Delay	23% decrease *(High priority)* No change *(Medium or Low priority)*

(Exhibit 4 continues to the next page)

U.S. Experiences *Field Studies*	Measure	Result
St. Cloud, Stearns County, MN (20)	Bus Delay	43% decrease
	Average Bus Occupancy	24 *(to balance the increase in person delay for non transit traffic)*
Anne Arundel County, MD MDSHA Opticom (21)	Bus Travel Time	13 to 18% decrease
	Auto Travel Time – Same Direction	9% decrease
	Auto Travel Time – Opposing Direction	4 to 5% increase
Los Angeles, CA Metro Rapid (22)	Bus Travel Time	8 to 10% decrease
Los Angeles, LADOT, Ventura Blvd and Santa Monica-Beverly Hills-Montebello Route (23)	Bus Travel Time	22 to 27% decrease
San Francisco, CA (24)	LRT and Trolleys Travel Time	6 to 25% decrease
San Diego, CA (25)	Trolley Travel Time	2 to 3 minute decrease over a section of 4.8 km
Seattle, WA Rainier at Genesee (26)	Bus Signal Delay	57% decrease
	Bus Intersection Stops	50% decrease
	Bus Travel Time Variability	35% decrease
	Intersection Person Delay	13.5% decrease
	Side Street Effects	Not significant
Seattle, WA Rainier Avenue (27)	Priority Bus Delay	34% decrease
	Bus Intersection Stops	24% decrease
	Bus Travel Time	8% decrease
Tacoma, WA Pierce Transit Agency Opticom(28)	Bus Travel Time	5.8 to 9.7% decrease *(green extension)* 8.2% decrease *(green extension and/or early green)*
	Side Street Impacts	Not significant

(Exhibit 4 continues to the next page)

Experiences Outside the U.S.	Measure	Result
Vicenza, Italy Opticom [29]	Bus Travel Time	23.8% decrease
	Bus Travel Speed	30% increase
Swansea, England SCOOT [29]	Bus Travel Time	2% decrease *(passive priority)* 11% decrease *(green extension/red truncation)* No change *(green extension)*
	Non Transit Vehicle Delay	17% increase *(passive priority)* 7% increase *(green extension/red truncation)* 15% increase *(green extension)*
Leeds, England SPOT [30]	Bus Travel Time	10% decrease
	Non transit Vehicle Travel Time	No change
Stuttgart, Germany [29]	Light Rail Transit Delay	50% decrease *(conditional priority)*
	Private Vehicle Delay	Minimal
Toulouse, France [29]	Bus Travel Time	11 to 14% decrease
	General Traffic Travel Time	Not significant change
Strasbourg, France [29]	Transit Vehicle Travel Time	4 to 5% decrease
Zurich, Switzerland [29]	Bus Waiting Time	Zero *(at 90% of signalized intersections)*
Toronto, Canada [31]	Street Car Signal Delay	15 to 49% decrease
Sapporo City, Japan Route 36 [32]	Bus Travel Time	6.1% decrease
	Bus Signal Stopped Time	20.8% decrease

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Exhibit 5: Sample Travel Time Results for One Hour Simulation Run AM Peak, U.S. 1, Fairfax County, Virginia

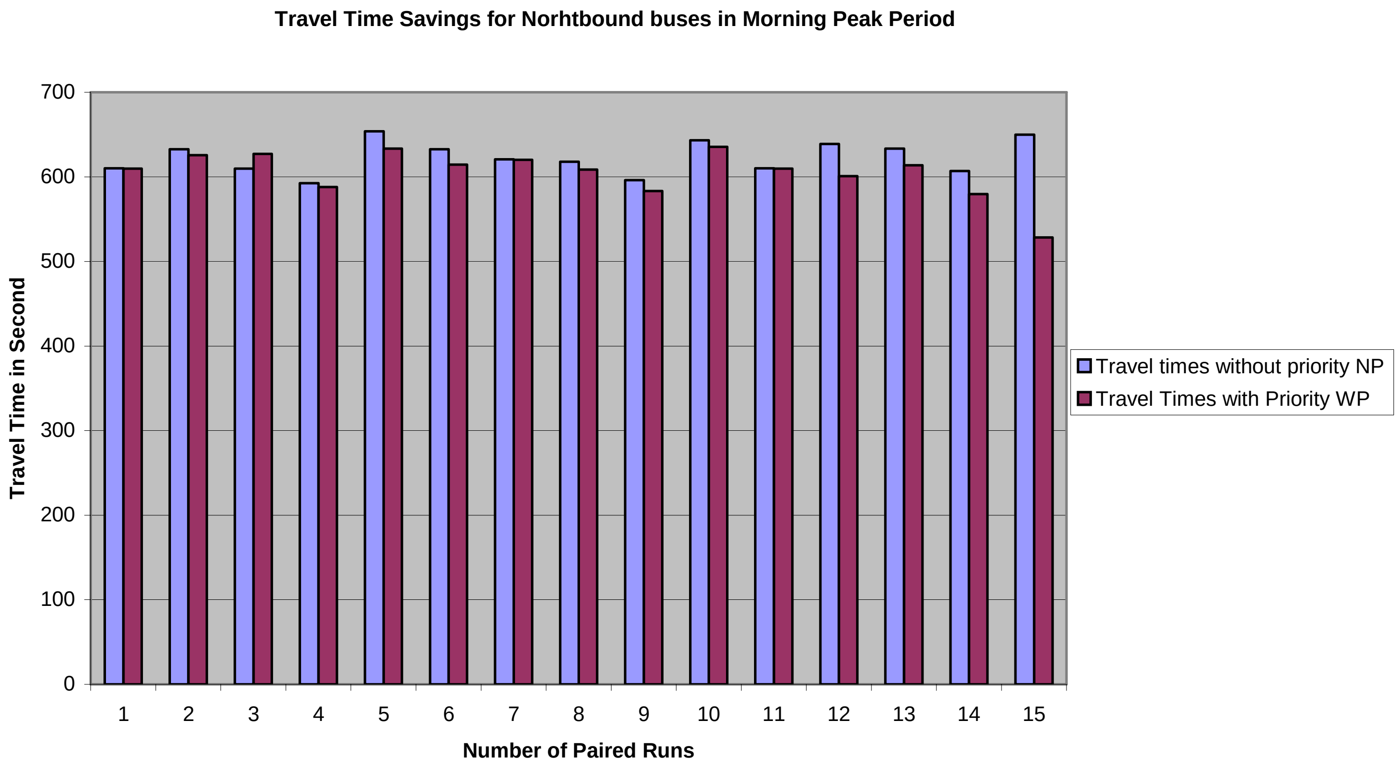
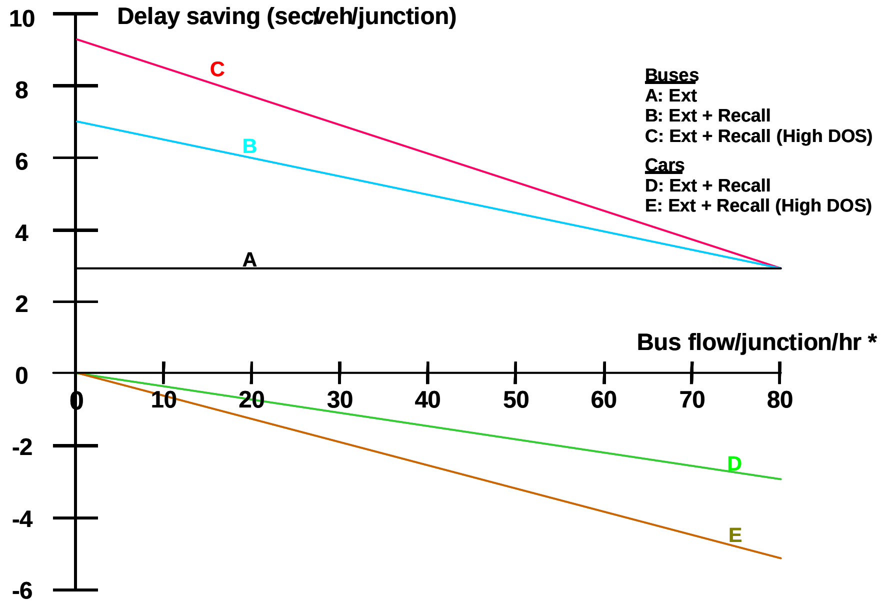


Exhibit 6: Impacts of Transit Priority Strategies on Buses and Cars

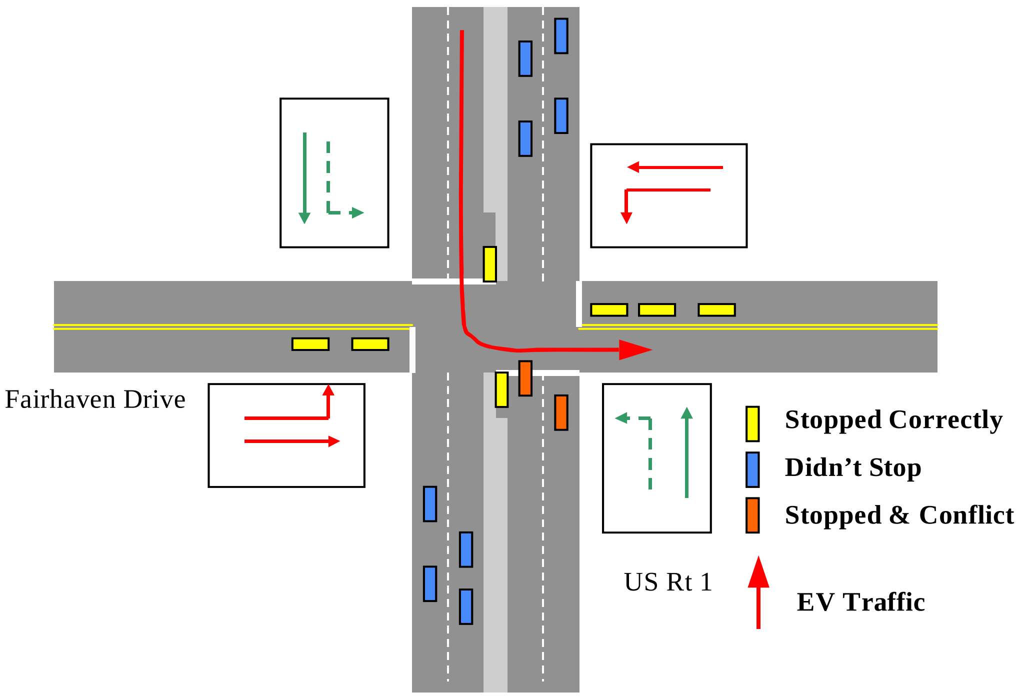


*** Bus flow/junction/hr = Number of buses given priority/intersection/hour**
Ext = Green extension
Recall = Red truncation
DOS = Degree of saturation

Source: Hounsell, N.B. and Mc Leod, F.N., “Automatic Vehicle Location: Implementation, Application and Benefits in the United Kingdom,” Transportation Research Record, No. 1618, pp. 155-162, National Academy Press, Washington D.C., 1998.

This chart illustrates the impacts on buses and cars of three transit priority strategies: green extension, green extension plus red truncation and green extension plus red truncation in a high degree of saturation. The green extension strategy (Line A) provides a constant benefit to buses at all headways with no negative impact to other traffic.

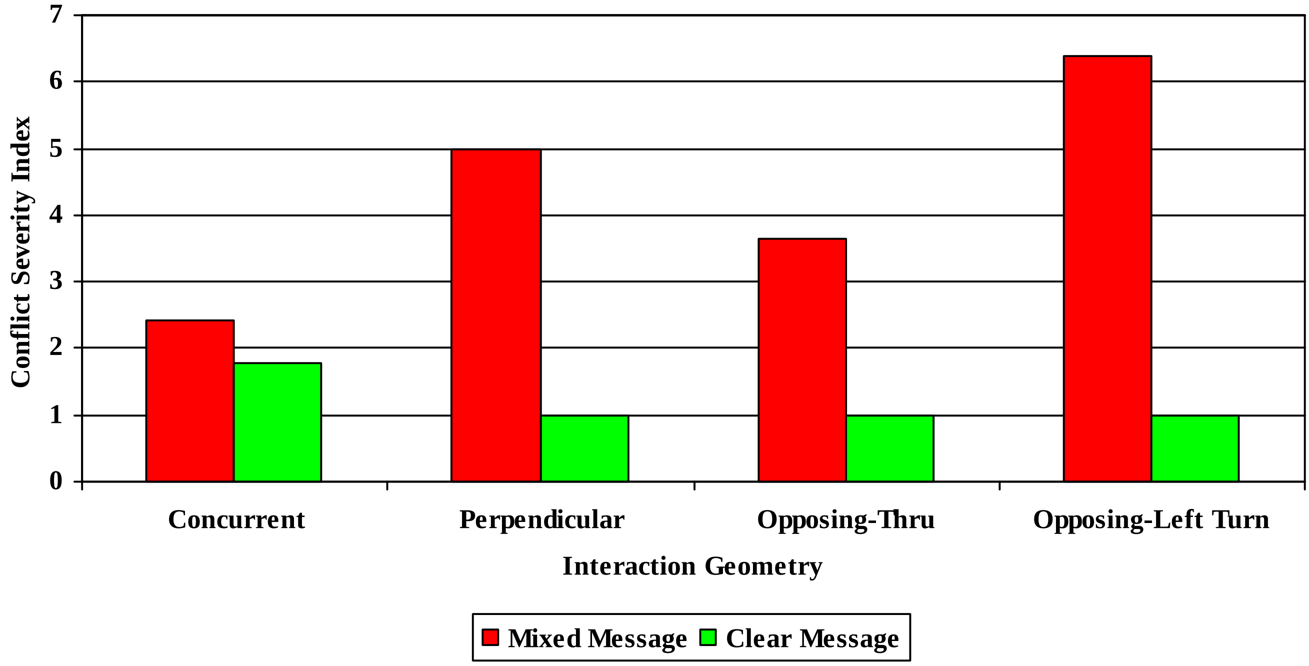
Exhibit 7: Conflict Point Analysis Illustrative Example



Source:
Louisell, C., Collura, J., and Tignor, S., *A Proposed Method to Evaluate Emergency Vehicle Preemption and the Impacts on Safety – A Field Study in Northern Virginia*, presented at the ITS America 2003 Annual Meeting and Exposition – Minneapolis, MN, May 2003.

This is an illustrative example of how the conflict point analysis technique can be applied to score potential EV crash encounters. The above figure illustrates a situation in which the vehicle interaction geometry includes an opposing left turn by the emergency vehicle. The potential EV crash encounter involves a southbound EV attempting to execute a left turn from a through lane. This will setup a potential conflict with northbound traffic proceeding under a green signal. The conflict point analysis technique provides a means to assess this potential crash and identify remedial actions.

Exhibit 8: Mean Conflict Score: An Illustrative Example



Source: Louisell, C., Collura, J., and Tignor, S., *Proposed Method to Evaluate Emergency Vehicle Preemption and Safety Impacts*, presented at the Annual Meeting of the Transportation Research Board, January 2003.

This chart depicts the before and after preemption conflict scores for the four vehicle interaction geometries: the concurrent case, the perpendicular case, the opposing-thru case and the opposing-left turn case. The results indicate that preemption reduces the conflict scores in both the opposing-through and opposing left turn cases. This suggests that preemption may reduce the potential of EV crashes in these two cases of vehicle interaction geometry.

Exhibit 9: ITS Investment and Physical Infrastructure Investment Differences

Criteria	ITS Investment	Physical Infrastructure Investment
Investment Cost	Relatively small (2-4 million)	Usually high (100-200 million)
Lifetime	Short/Medium (5-10 years)	Long (30-50 years)
Salvage Value after Depreciation	Usually no value	Significant value (~20% of investment cost)
Operating Cost of the System	Significant to total costs	Insignificant
Effects on Other Costs of the Road Authority	Indirect (efficiency of winter maintenance)	Direct (repair and maintenance costs)
User Costs	Accident and time costs often cancel each other out	Usually all user costs decrease

Source: Leviakangas P. and Lahesmaa,J., "Profitability Evaluation of Intelligent Transportation System Investments," Journal of Transportation Engineering, May/June 2002, pp. 276-286.

Exhibit 10: A Request for Proposals to Procure an Emergency Vehicle Preemption and Transit Priority System

A Request for Proposals from System Vendors to Procure an

Emergency Vehicle Preemption and Transit Priority System

Along U.S. Route 1 in Fairfax County, Virginia

Table of Contents

1.0 Purpose

The purpose of this request for proposals (RFP) is to solicit bids from system Vendors for the procurement, installation, and maintenance of an emergency vehicle preemption and transit vehicle priority system to be deployed along a segment of U.S. Route 1 in Fairfax County, Virginia. An underlying aim of the RFP is to seek the most efficient and cost effective system to meet the requirements described in the RFP.

Vendors shall: a) clearly identify the technology and design proposed; b) provide objective data and information to show that the proposed system meets the intended requirements; c) provide and install the system including all equipment, software and other necessary components; d) maintain the system for a specified period of time; and e) provide data to facilitate system performance evaluation to be conducted by others.

2.0 General System Description

A generic depiction of the emergency vehicle preemption and transit signal priority system is provided in Exhibit A. As depicted, a device located on an emergency or transit vehicle communicates with the signal controller within a predetermined distance of the intersection. An emergency vehicle would be provided an “unconditional” green interval (i.e. preemption) in a safe and efficient manner as soon as all other necessary movements are provided a red interval. A transit vehicle would be provided a “conditional” green interval (i.e. priority) only if certain conditions prevail (e.g. no emergency vehicle request has been made and the existing interval in the direction of the transit vehicle is green and thus only a limited, green extension will be provided; if the signal interval in the direction of the transit vehicle is red when the transit priority request is made, the request is ignored).

The emergency vehicle preemption and transit priority system will be installed in the vicinity of one or two (1 or 2) firehouses along U.S. Route 1 where four bus routes also exist. Major participants in the project will include the Virginia Department of Transportation (VDOT), Fairfax County, Virginia Tech, and the Vendor. VDOT maintains the traffic signal system. Fairfax County operates the major firehouses in the corridor and three of the four bus routes. Virginia Tech will be instrumental in conducting the system performance evaluation. The major responsibilities of the Vendor are to provide, install and maintain the system and its components. These responsibilities would be carried out in coordination with VDOT, Fairfax County transportation, fire and rescue officials, and Virginia Tech.

3.0 System Requirements

3.1 General Requirements

A. A major requirement of the system is to provide emergency and transit vehicles a specified form of preferential signal treatment in a safe and efficient manner at selected, signalized intersections along U.S. Route 1 in Fairfax County, Virginia. The system must be fully functional, reliable, easily maintainable, easily expandable, and easily upgradeable to new technologies and requirements. The system shall also be compatible with existing Fairfax County Fire and Rescue opticom equipment. To this end, the system should use to the largest extent possible commercially available off-the-shelf components with well-established records of reliability and performance. An underlying objective of this system is to improve emergency vehicle and transit travel time and to increase safety along U.S. Route 1. Other system requirements are stated below.

B. The installation of the emergency vehicle preemption and transit priority system will be at seven intersections along U.S. Route 1 as shown in the Exhibit B. An aim of this installation is to examine the functionality of the system when emergency vehicles and transit buses pass through the intersections. Vendor shall supply four (4) in vehicle devices for emergency vehicles and six (6) in vehicle devices for transit vehicles. Vendor shall also supply and install fifteen (15) detectors/readers in the specified intersections. The installation of in vehicle devices shall be done in coordination with the respective agencies.

C. The Vendor shall maintain the system for ninety (90) days following the acceptance of the equipment by VDOT.

D. The system shall be able to detect a vehicle within 500 to 1000 ft from the intersection.

E. An emergency vehicle shall be provided an "unconditional" green interval (i.e. preemption) in a safe and efficient manner as soon as all other necessary movements are provided a red interval.

F. A transit vehicle shall be provided a "conditional" green interval (i.e. priority) only if certain conditions prevail (e.g. no emergency vehicle request has been made and the existing interval in the direction of the transit vehicle is green and thus only a limited, green extension will be provided; if the signal interval in the direction of the transit vehicle is red when the transit priority request is made, the request is ignored).

G. Each preemption and priority request shall be acknowledged with a confirmation device. The priority device shall provide confirmation outports.

H. The system shall log preemption and priority requests, including but not limited to date, time, direction and vehicle ID. Preemption and priority requests shall be given only to vehicles with valid vehicle ID's.

3.2 Hardware Requirement Details

The Vendor shall provide a functional overview indicating their understanding of the equipment and data interfaces and protocols.

A. Equipping emergency and transit vehicles:

The system shall be capable of handling all vehicles provided with vehicle ID's without requiring additional hardware or software modifications other than those installed on the vehicles for the purpose of preemption and priority. Each vehicle, which is requesting either preemption or a priority, shall have a unique identification number (I.D.). The Vendor shall provide technical data on the tamper-resistant features of the equipment. The Vendor shall describe the method of response between the in-vehicle device and the detectors.

B. Monitoring vehicles equipped – common features

The Vendor shall provide field equipment that reads and stores the information including, but not limited to date, time, direction, and requesting vehicle ID as each vehicle approaching that intersection makes a preemption or priority request. The transmission rate from the point at which the request is made to the point at which traffic controller receives the request should be less than or equal to 0.3 sec. The Vendor shall provide independent, operational test data detailing a system capture rate of ninety-nine percent (99%) accuracy for a similar application. The source and the methodology shall be acceptable to all the partners. Examples of acceptable sources of test data include public agencies, such as federal and state departments of transportation that will certify that the test is independent and non-biased. The equipment shall have the ability to communicate directly with a PC-based computer system or a portable laptop computer. The Vendor shall provide copies of the software used to interface with the device. The Vendor shall provide information regarding the format of data from the controller to a computer. The computer system shall retain stored data in the event of a power interruption. Any power failure will be logged and only that data being logged at the time of power failure will be lost. The system should log the time of power-up. The Vendor shall provide technical data as how the data is collected, verified, retained and transferred to the interface module, central computer, and a portable PC. The Vendor shall specify the equipment required for transferring data to a computer. The Vendor shall describe the operational speed range for the in-vehicle device to be successfully read. Describe the percentage of devices read at 0-20 mph, 20-30 mph, 30-50 mph, and > 50 mph. The Vendor shall substantiate these claims with independent operational test data with the Proposal. The Vendor shall describe the probability of decoding and /or reporting incorrect vehicle identification and details of security provisions.

3.3 Product Viability

A. Workmanship

The hardware furnished under these specifications shall be the latest approved model in the current production, as offered to commercial trade, and shall be quality workmanship and material. The successful bidder shall represent that all equipment offered under these specifications is new. Used, shopworn, demonstrator, prototype, re-manufactured, reconditioned, or discontinued models are not acceptable. Equipment shall conform to the specifications and applicable requirements of the specifications of the Underwriters Laboratories Incorporated (UL), the Institute of Transportation Engineers (ITE), the National Electrical Manufacturers Association (NEMA TS-1), and the regulations of VDOT and the Fairfax County. All external screws, nuts, and locking washers shall be stainless steel; no self-tapping screws shall be used unless approved by the partners. All parts shall be made of corrosive resistant material, such as plastic, stainless steel, anodized aluminum or brass. Additional requirements for in-vehicle components are defined in Paragraph C of this subsection.

B. Standard Parts

All parts even if not specified in this document, but which are necessary for the equipment to be complete and ready for operation, or which are normally furnished as standard equipment, shall be furnished at installation time by successful bidder. All parts shall conform in strength, quality, and workmanship to the accepted standards of the industry.

C. Additional Performance Characteristics - Vehicle Mounted Equipment

1. Durability: Describe the materials, construction methods, design details, and other characteristics employed to ensure the equipment is durable

and can withstand the rigors of normal operation for a minimum useful life of ten (10) years.

2. Equipment Interfaces: Verify each interface's compliance with the requirements of SAE Recommended Practice J1708 or equivalent.

3. Operating Environment: Verify equipment compliance with SAE Recommended Practice J1455 and its ability to operate and not suffer any degradation in performance, corrosion, deterioration, or abnormal wear under the following conditions:

- Storage temperature: -25 to +150 degrees Fahrenheit, ambient
- Operating temperature: -10 to +110 degrees Fahrenheit, ambient
- Ambient humidity range: 20 to 95 percent relative humidity (non condensing)
- Inclination: 0 to 18 degrees off vertical
- Dust: Airborne particles and dust encountered in revenue service and caused by interior bus cleaning with the use of cyclone-type vacuum machines.
- Moisture/Water: Moisture/water from wind-blown rain, passengers, water from interior and exterior bus/car wash equipment.
- Vibration/Shock: Requirements as specified in Factory Acceptance Test
- Electromagnetic effects: Requirements as specified in Factory Acceptance Test
- Verify that the equipment will not be subject to interference from the emergency vehicle or transit buses radio system and other onboard devices.

4. Vehicle Power Supply: Verify the ability of the equipment to operate, if required, under nominal voltage conditions and specify the operating range in terms of volts dc. In addition to the above electrical characteristics, the ability of the equipment to withstand sustained voltage levels for an extended time period shall be specified. The equipment shall not suffer damage or lose data in memory when the supply is increased to

the specified level (vdc) by the vendor. The equipment shall not suffer damage or lose data in memory when the supply is increased to the specified level (vdc) by the vendor. The equipment shall not suffer damage or corruption of data as a result of very high short duration peak voltage.

5. Circuit Boards/Connectors/Wiring Harnesses

If applicable, the circuit boards within the equipment shall utilize state of the art technology through-hole plating, solder masking, and component-identification silk screening. Circuit cards, if applicable shall employ pin/socket connectors, whether physically on the card-edge fingers. All socketed devices and all connectors, whether physically on the circuit boards or in other wire harnesses, shall employ some type of positive lock and shall utilize machined pins with gold plating. Devices in non-locking IC sockets shall be “tie-wrapped” in place.

D. Copies of Literature and Specifications

The Vendor shall provide a copy of the manufacturer’s standard published literature in their bid package for each bid item. The Vendor shall submit out sheets with the bid package. Technical and standard published literature submitted shall be used to determine compliance with all relevant specifications contained in this document. The Vendor shall state in writing all exceptions to any specifications.

3.4 Installation Requirements

A. The Vendor shall install any features necessary for the hardware to operate properly.

B. The Vendor shall procure all permits and licenses, as necessary.

C. The Vendor shall furnish all labor, tools, equipment, and incidentals necessary to complete the installation in an efficient and workmanlike manner.

D. The Vendor shall install the equipment and cabling in a professional manner that is least disruptive to traffic operations.

E. VDOT has the right to change or delete any or all installations prior to installation. The Vendor shall be notified in writing of any changes or deletions as they occur. Upon the deletion of an installation site, there will be no equipment costs or installation costs charged to VDOT associated with the deletion.

3.5 Training Requirements

The Vendor shall provide operational and maintenance training to personnel designated by VDOT and Fairfax County during installation, testing, and debugging. This training shall be provided through practical demonstrations, seminars, and other related technical procedures. Operations and maintenance manuals shall be provided for each trainee.

The training shall include, but not be limited to, the following:

A. Hands-on operation for each type of equipment
B. Explanation of system commands, their function, and their usage
C. Required preventive maintenance procedures
D. Servicing procedures
E. System troubleshooting or problem identification procedures
F. Recommend spare parts

3.6 Documentation

Documentation in the form of manuals and electronic media in a form acceptable to VDOT and Fairfax County shall be provided. They shall include the following: two (2) copies of the System Operations Manual. The Vendor shall include one (1) copy on an electronic file.

3.7 System Testing and Acceptance

A. General Vendors are required to submit out sheets for all equipment with proposals for review. The objective of the equipment test program is to ensure that the equipment furnished under this contract shall meet all the requirements specified in this document, including operation under environmental stress conditions. Testing and acceptance shall be conducted to satisfy production and delivery schedule requirements. The tests to be conducted shall be the following:

- Pre-Installation Checkout (PIC)
- Installation Acceptance Test (IAT)
- Maintenance Period

B. Methodology

The following steps define the methodology for conducting the Equipment Test Program:

1. Submission of out sheets for all equipment parts shall be a prerequisite to produce the equipment to be furnished for the Pre-Installation Checkout (PIC). The purpose of the PIC shall be to demonstrate that the equipment performs its functions in the manner specified prior to go ahead for the Installation Acceptance Test (IAT). One unit shall be delivered to the VDOT repair shop at camp 30 to verify the compatibility of the equipment with current 170 equipment of VDOT. The PIC shall include an onsite demonstration at a VDOT designated intersection. Tests shall verify proper installation and interfacing of the equipment. PIC details are specified in the paragraph G of this subsection.
2. Upon successful completion of PIC, VDOT production release for seven (7) intersections, six (6) emergency vehicles and twelve (12) transit vehicles installation will be issued. IAT shall be conducted for a period of 70 days and will test the accuracy of the system at

the end of this period. The equipment shall be accepted or rejected by the county and VDOT.

3. Upon completion of the IAT, the maintenance period shall be for ninety (90) days. VDOT's final acceptance of the system is contingent upon successful completion of this period. Warranty period shall begin upon successful completion of this period. The details are specified in paragraph H of this section.

C. Test Plan

For all tests to be conducted, a test plan and procedures shall be submitted for VDOT's approval at least thirty (30) days prior to the start of each test. The Vendor shall prepare a test plan and applicable procedures, which shall govern the conduct of activity, surveillance, direction, and methods of observing and recording the pertinent data. VDOT shall approve the test plan prior to proceeding with testing. At least the following elements shall be included in the test plan:

1. Dates, times and locations of testing
2. Support and calibration tools and instrumentation to be used
3. Technical publications to be referenced
4. Spares and consumables to be available
5. Maintenance facilities needed
6. Staffing requirements to be met
7. Scheduling of personal
8. The format and specific data to be collected during the test period together with the method used to report the test results
9. Preventive maintenance tasks to be performed during the test

D. Test Procedure Outline

1. The test procedure shall be in IEEE format or an approved equivalent. It shall include, as a minimum, the following requirements:

a. Objective of test

b. Test environmental conditions

c. Detailed description of test specimens including drawings, part numbers, inspection and test records, maintenance records, and calibration records

d. Detailed procedure of test

e. Test equipment to be used. Include any measuring equipment and/or any equipment aiding in the performance of the tests

f. The level and schedule of preventive maintenance during the test

g. Pass/Fail Criteria

h. Retest procedure

i. Test data sheet format

j. Test Notification to engineer

k. Test reports

2. Test failure resolution

The test procedures shall describe the process to be followed for the resolution of test problems, failure recurrence control, and general test conduct ground rules.

E. Test Reporting

The Vendor shall provide a complete report documenting the operation and reliability during the acceptance testing. The report shall be in a form acceptable to VDOT.

F. Factory Acceptance Tests (FAT)

Vendor shall submit out sheets with the bid.

G. Pre Installation Checkout (PIC)

VDOT will issue a production release to the chosen Vendor to deliver all equipment specified for the PIC. Prior to installation, a PIC test will be conducted in two phases. The Vendor shall provide and install test benches at the chosen intersections which will be set in such a manner as to permit the evaluation of subject equipment to the following PIC test objectives:

1. To visually inspect a random sample of the system components for conformance with specifications.
2. To confirm that there was no visible damage in delivery of equipment.
3. To verify that the system components work as expected by exercising them to check their operating functions.
4. To ensure that all simulated data reports are produced.
5. To determine if installation can begin or if corrections and/or adjustments are needed followed by a retest, before installation can begin.

The PIC test will be conducted in the following two (2) phases:

Phase 1 - Shop testing

The following sequence of tests shall be conducted as a minimum. Phase1 shall be conducted at VDOT facilities to determine that the equipment has no negative effects on other equipment. One unit shall be delivered to the VDOT repair shop at camp 30. The interface module shall be programmed to perform the conditional functions as identified in subsection 3.1. E and 3.1.F.

a. The interface module shall create the event log including, but not limited to at least date, time, direction and vehicle I.D.
b. The interface module shall send the input that will be accepted by each controller type.
c. Visual inspection of the system will be made to ensure that there is no physical damage and that all confirmation displays or messages and conditional functions as described in sections 3.1E and 3.1F are performed.

The schedule for Phase 1 testing shall be finished within thirty (30) days.

Phase 2 - On-site Demonstration

Upon successful completion, Phase 2 shall consist of an on-site demonstration with both transit and emergency vehicle and a single street intersection determined by VDOT. A one (1) week test period shall begin when VDOT receives notification from the Vendor that the following has been accomplished:

a. All field equipment is installed and operational
b. All data transmission equipment is installed and operational
c. All required in-vehicle equipments are mounted on each transit and emergency vehicle

Phase 2 testing shall verify that the information from the system can be read, transmitted to a portable computer, displayed on the portable computer, and stored on a portable computer. Phase 2 testing shall also verify that all information from in-vehicle equipment can be transmitted to the interface module, the proper signal is sent to a signal controller, and the event log information is stored and downloaded to a portable computer from the interface module. Successful completion of PIC shall be a prerequisite for the start of the IAT. Satisfactory performance shall be approved by VDOT.

H. Installation Acceptance Test (IAT*)*

The IAT shall start after a seven (7) day settling period when the system has been installed and installation check out is complete at a designated VDOT location and all equipment is functioning in the manner specified. During this period, the Failure Review Board (FRB) shall be established in conformance with guidelines specified in **subparagraph I**. The IAT shall be conducted for seven (7) days to verify the accuracy of the system and a ninety (90) day maintenance period to verify the reliability of the system.

1. Priority of tests

The IAT shall be performed at seven (7) intersections identified in Exhibit B. The 7-day test period shall begin when VDOT receives notification from the Vendor that the following has been accomplished:

a. All field equipment is installed and operational
b. All data transmission equipment is installed and operational
c. All in-vehicle equipment components are mounted on all designated eighteen (18) vehicles, and the information from in-vehicle equipment can be read, transmitted to, displayed on, and stored in the base and portable computer.
d. All information from the system can be transmitted to the interface module, the proper signal is sent to signal controller, and the event log information can be downloaded to a portable laptop PC from the interface module.

2. Responsibility of equipment during tests

   The Vendor shall be responsible for all equipment maintenance before and during all testing. The Vendor shall provide adequate spare modules, parts, and assemblies to complete the IAT. Should the Vendor-supplied equipment fail the acceptance testing, VDOT will notify the Vendor and require the Vendor to supply and install replacement equipment. The replacement equipment shall pass all acceptance testing as defined in the document. The replacement equipment shall be provided at no additional cost to VDOT.

3. Seven-day test period

   The length of the test period shall be seven (7) calendar days. The entire system shall be operational and shall have successfully recorded ninety-nine percent (99%) of the priority and preemption calls that were made in the intersections of concern during a 30-day period. The system shall have accurately logged and transmitted the signal to the low priority input to the traffic signal controller at a 99% accuracy rate. At the discretion of VDOT, time shall be suspended or restarted if the system fails to operate correctly.

4. Ninety (90) - day maintenance period

   The length of the test period shall be 90 calendar days. The test shall be over a 90-day period during which time the entire system shall be operational and shall have successfully recorded more than ninety nine percent (99%) of the priority and preemption calls that were made in the intersections of concern. The system will have accurately logged and transmitted the signal to the low priority input of the traffic controller at a ninety-nine (99%) percent accuracy rate. At the discretion of VDOT, time shall be suspended or restarted if the system fails to operate correctly.

5. Testing criteria

   During the 7-day and 90-day periods, it is assumed that there will be a minimum of two-hundred (200) test transit and emergency vehicles traveling on the intersections shown in **Exhibit B** equipped with the proposed system.

   a. The Vendor shall record, on a portable PC, the information including, but not limited to date, time, direction and vehicle ID for each request. The Vendor shall provide a written copy of the daily records in the portable PC to the above mentioned agencies within twenty four (24) hours.
   b. The above mentioned agencies shall compare the records of the provided data with scheduled route information that lists each of the test vehicles and their expected routes of travel as defined by the system. The comparison shall note any discrepancies between the expected and the actual travel routes. Each discrepancy noted shall be examined by the agencies to determine if the system failed to read any priority or preemption calls that were made. If it is confirmed that the vehicle passed through one of the intersections (that are in the test area) and the corresponding record is not recorded, the event shall be noted as a missed event and shall be charged against the accuracy requirement of the system.

c. The agencies mentioned above shall provide the Vendor with a list of missed calls within 24 hours of receiving the report. It shall be the Vendor's responsibility to determine if there is a failure of the system; it's probable cause, and time it will take to correct the problem.
d. The Vendor shall provide these agencies with a written explanation of the probable cause for the failure and the time it will take to correct the problem. The agencies shall then decide if it is warranted to suspend time (see paragraph 6.a below) or if it will be necessary to restart the test period (see paragraph 6.b below).
e. If part of the system is malfunctioning such that the testing period is to be suspended, then the testing for the entire system shall be suspended. If part of the system is malfunctioning such that the testing period is restarted, the testing for the entire system shall be restarted.

6. Adjustments to test periods

   The types of test period adjustments to be enforced in this project are as follows:

   a. **Suspension of time** - when the failure and the correction may require a short time to implement. Time suspension shall begin when the failure is first noticed, and it shall extend only as long as required to correct. Once corrected, the time of the test shall resume with the number of days completed at the time of the failure.
   b. **Restart of the time** - when the failure may be more serious and require more time to correct. **Once corrected, the time of the test shall start at zero for the 7-day test period and for the 90-Day maintenance period.**

When restarting, the adjustments to make to the acceptance testing time periods, failures in the operation of the system will be grouped into two categories.

1. Type 1 failures - those that involve conditions that are beyond the control of the Vendor, failures of a minor nature that are easily and quickly corrected, or failures that are expected of a new installation.
2. Type 2 failures - those that involve conditions that are within the control of the Vendor, failures that are related to the system design, or failures that may be of a minor nature but have not been easily or quickly corrected.

Type 1 failures shall result in the test period being suspended for the time necessary to make the corrections, and the testing shall begin again at the point in time of the failure; Type 2 failures shall result in the test period being restarted at time zero for the 7-day test period after the corrections are made, and at time zero days for the 90-day maintenance period. The costs for repairing, replacing, or correcting the malfunctioning equipment shall be the responsibility of Vendor. The definition of the types of failures will differ with the two test periods.

The definitions of failures for the 7-day test period are as follows:

1. Type 1 failures - electrical power outages, telephone line outages, adjustments to antenna alignment, and equipment malfunctions. If a second equipment failure occurs in the same device, the Vendor shall prove that the failures were different in order to be classified as a Type 1 failure.
2. Type 2 failures - if a second equipment failure is determined to be the same as the first; a third failure of any description occurs in the same device, then after the repair or replacement is made and the system is made operational; design deficiencies; interferences due to ambient conditions; software problems; any other failures that

can be classified as Type 1 failures; and the system failing to meet ninety-nine percent (99%) accuracy criteria.

For the ninety-day (90) maintenance period, the definitions of failures are as follows:

1. Type 1 failures - Telephone line outages attributed to third party communication failures; electrical power outages; adjustments of sensing equipment shall be a Type 1 failure until the number of adjustments equal three (3) for the same antenna.
2. Type 2 failures - Electrical component failure, multiple adjustments to the same sensing equipment in excess of three (3); any disruption to service that can not be classified as a Type 1 failure; and the system failing to meet the ninety-nine percent (99%) accuracy criteria. The Failure Review Board (FRB) shall include four members selected by VDOT, and a member selected by the Vendor. The FRB shall determine what constitutes a failure and what the satisfactory corrective actions shall be to prevent recurrence. Failures shall be established in conformance with guidelines specified in paragraph 3.7.H.6

3.8 Warranty

A. Warranty Coverage

All manufacturer warranties shall be transferred to VDOT at the end of the maintenance period. Warranties in this contract are in addition to any statutory warranties or remedies. The Vendor hereby warrants and guarantees to VDOT that all work performed or furnished under this contract shall be free from all defects and related defects under normal operating use and service, including without limitation defects in design, material, and workmanship. “Work” means and includes anything and everything to be done and provided for in the execution, completion and fulfillment of the contract.

B. Warranty Period

1. The Vendor shall provide the warranty for a period of twelve (12) months following successful completion of section 3.7. The warranty shall cover all parts and labor costs associated with the repair of the work during the twelve (12) month period.
2. The warranty period shall extend to cover the completion of all remedial work to correct any and all deficiencies under warranty. No warranty shall expire until all warranty obligations of this contract are met.

C. Complete or Partial Unit Replacement

In the event of any defect in design, material or workmanship of a unit, competent or subassembly under warranty, VDOT shall consider (in consultation with the contactor when possible) whether the unit, component or subassembly is to be replaced in its entirety or whether it is to be repaired and defective parts replaced. VDOT's decision as to which alternative will be used will be based upon minimizing downtime and total repair costs of the unit, component or subassembly and as to whether or not failure may be detrimental to the life of the total assembly.

D. Warranty Conditions

1. No warranty period shall end unless the complete finished documentation specified herein is provided by the Vendor and is approved by VDOT.
2. VDOT's maintenance, use and operation or any part thereof, including all equipment and systems listed above, shall not defeat, limit or in any way affect the warranties of this Contract if the Vendor has not provided adequate, correct and complete training, maintenance manuals, operating manuals. Electrical and electronic schematics, mechanical diagrams and documentation of microcomputer programs.

E. Negligence

The warranty shall not apply to any equipment which has been damaged through accident or negligence, or which has been subjected to other than normal use, or acts of God. Temperature, humidity, vehicle vibration and ambient electrical conditions described herein shall be considered normal operating conditions for this equipment.

F. Consumable Items

The Warranty shall not cover the replacement of normal consumable items or items which are replaced in usual and scheduled preventive maintenance programs, such as light bulbs and wear-related items, unless they fail due to defective manufacture, improper installation by the Vendor, or defects in design of the part of the system within which the part functions.

G. Reliability Requirements

The equipment reliability shall be in accordance with the criteria identified in Subsection 3.7.

H. Design Defects

If during the said warranty period the rate of failure of any part or component, from any one cause or from various causes, exceeds twelve percent (12%) of the mean quantity of such item delivered to VDOT, then the entire quantity of such item shall be considered to have failed, and shall be repaired, corrected, or replaced as hereafter provided.

The warranty on items determined to be design defects shall be extended for the time of the original warranty. This extended warranty shall begin on the repair/replacement date for the corrected items.

I. Warranty Repairs

1. Vendor shall be responsible for all the repair and/or replacement of components removed from the equipment supplied under this Contract, and which has been found to be defective in terms of design, material, workmanship, or function under the terms of the warranty.

2. All repairs shall be performed by the Vendor.

J. Repair Time and Liquidated Damages

Test repair and warranty repair shall be performed by the Vendor in a maximum of twenty-four (24) hours of the defect occurrence. The Vendor shall make available adequate resources for the replacement including test repairs and warranty repair, spare modules and spare components to support one hundred percent (100%) availability daily.

K. Compensation for Unresponsiveness

In the event of Vendor's failure to comply promptly with its obligations under these specifications or with a request from the agencies to repair, replace, or correct failed components, devices, equipment, and/or materials, the agencies shall, upon written notice to the Vendor, have the authority to deduct the cost of labor and materials from any compensation due or to become due to the Vendor. In the event the Vendor has been paid, Vendor shall agree to compensate the agencies for the costs thereof. The Vendor shall notify John Olivo at 703-383-2780, or designated representative, prior to accessing field equipment.

L. Access to Equipment in Service

The Vendor shall follow the proper VDOT security procedures for gaining access to field equipment and locations.

M. Repair Reporting

During the entire warranty period, any and all repairs/adjustments of equipment by the Vendor shall be documented by the Vendor. A repair report shall be submitted at the end of the week. Each repair or adjustment shall be documents by time, day, component, type of failure, or adjustment made and by whom.

N. Additional Warranties

If any Vendor to the Vendor offers warranty on a component or a subsystem that is longer than the required stated herein, the Vendor shall inform VDOT of this additional warranty period and pass said period through to VDOT.

4.0 Other Requirements of the Vendor

4.1 Qualifications and Experience

The successful Vendor shall be certified to do business in Virginia, and demonstrate experience in project management, emergency vehicle preemption and transit priority systems, and traffic signal systems. The Vendor shall designate for this contract a project manager, who will be the point-of contact to make decisions or provide coordination, as may be requested by the VDOT, county and agencies. The project manager shall demonstrate competency in all aspects of the type of service covered by this contract and a general knowledge of issues, policies and procedures. At a minimum, the project manager shall have obtained INSA Traffic Signal II certification.

4.2 Project Officer

The performance of the Vendor required by this contract is subjected to the review supervision and approval of the VDOT Traffic Signal Manager, or designated representative in Northern Virginia. VDOT may, at its option, designate additional persons as officials, in reference to fulfilling the contract obligations. Such persons will be identified to the Vendor in writing.

The Project officer shall be responsible for the following issues:

a) Receiving reports, inquires, and notices as required in this contract
b) Providing official notices, giving instructions, approving operating procedures, conducting inspections and addressing public comments and complaints
c) Monitoring performance, approving invoices and reports

5.0 Format of Response

All proposals shall be submitted in the order of the following items. Responses not answered shall be marked with 'N/A'. Offerors shall submit an original, plus four (4) copies (five copies total).

Item	Information Required

A. Completed proposal form, including authorized signature, name of Offeror, street address, city/state/zip, telephone number, facsimile number, email, name of person who can authoritatively respond to any question regarding the responses and signed insurance check list.

B. Description of the organization in 500 words or less (corporation, partnership, etc.) where organized, names and titles of officers.

C. Description of Offeror's experience, and indication of the number of years the Offeror has had experience with managing projects of the following:

1. Signal Systems
2. Transit Vehicle Priority System
3. Emergency Vehicle Preemption System
4. Project management experience

List any contracts currently underway in the transit priority and signal preemption or related field.

D. List and description of any other lines of business in which Offeror has a financial interest.

E. Evidence that the Offeror is a legal entity, duly organized, validly existing, and in good standing

F. References of all similar contracts completed within past five (5) years. Provide the name of contracting organization, locations, and description of Offeror's direct involvement, performance statistics, and the owner/manger contact person and telephone number.

G. List the detailed description of any operating or management contracts that the Offeror did not complete because of cancellation, default, or litigation in the past ten years.

H. List of any sub replaces, including the information required in Sections A, B & C for each.

I. Staffing plan, identifying by name and resume the project manager and corporate (off-site) staff proposed to support this contract. The staffing plan shall also detail the number of hours each staff member is estimated to work on each task of the project. Resumes for each staff member shown in the hourly estimate shall be provided.

J. General description of the work plan to accomplish each of the tasks listed in this RFP.

K. Time line for each of the tasks listed above.

L. Chart of time staff detailing the number of hours each staff person is estimated to work on each task of the project, on a monthly basis with a total for the contract period.

M. Detailed cost estimate, showing a detailed breakdown of labor rates, hours required for each category of labor, all materials, overhead, general and administrative costs and profit, for all of the tasks.

N. Identify any legal judgment against the firm in the past five (5) years and any litigation in process or pending. Identify nature of litigation or judgment and all parties' names.

O. Any other information (brochures, portfolios, etc.), which may help establish the Offerors qualifications, can may be bound separately and submitted with the proposals in the same number of copies as required for the proposal.

The finalists selected during the evaluation process may be required to provide a statement, signed by their chief financial officer, of their financial capability to undertake this project, and include one (1) copy of their latest annual report. This information will be considered confidential, and will NOT be made public record.

P. A copy of manufacturer's standard published literature.

6.0 Record Keeping

The Vendor shall assist the VDOT in meeting any reporting requirements that may be imposed for the granting or continuation of funding from local, regional, commonwealth or federal authorities. The Vendor shall retain records required by this contract for a period of four years from the conclusion of this contract.

Exhibit A: A Generic Description of the Emergency Vehicle Preemption and Transit Priority System

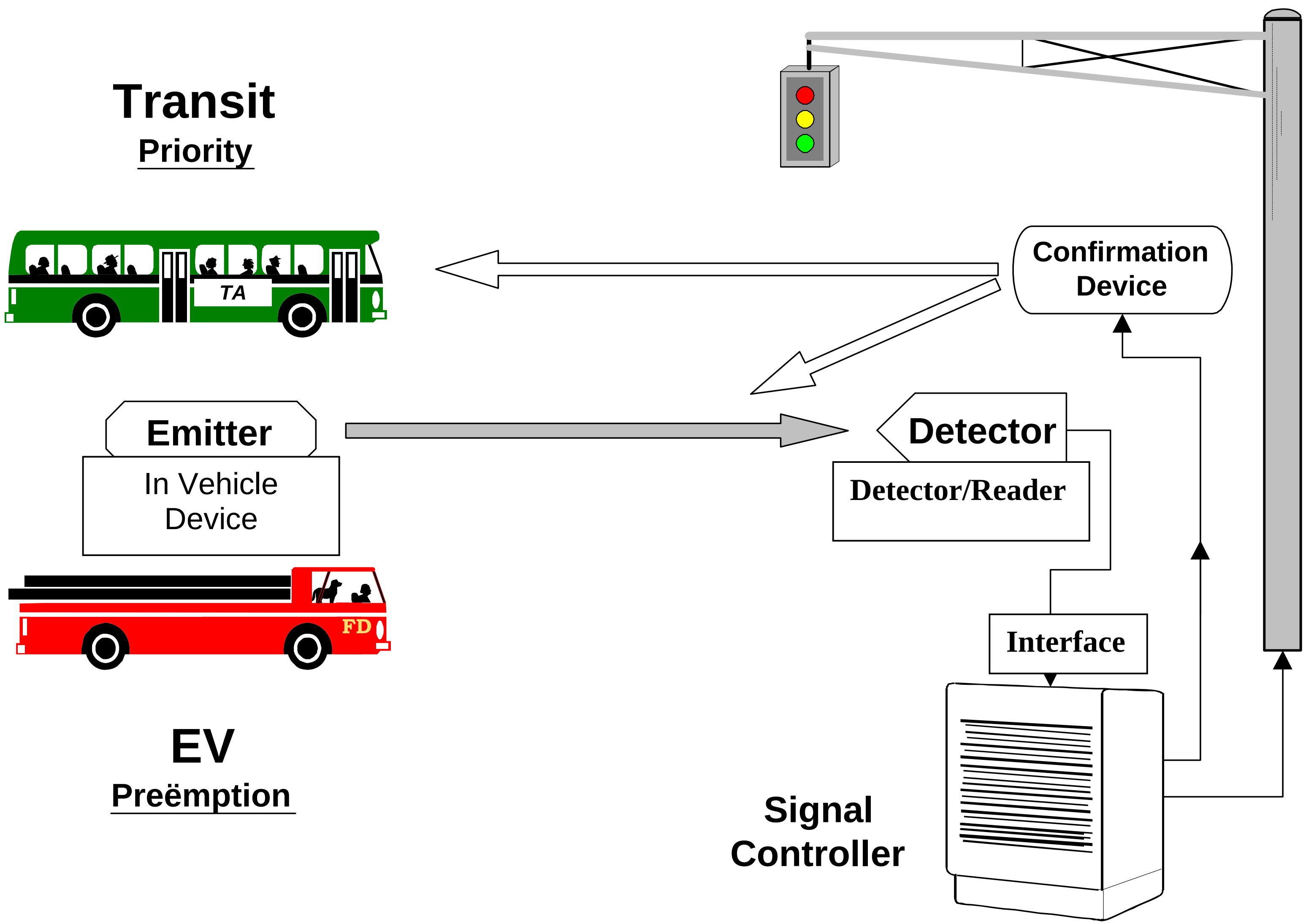
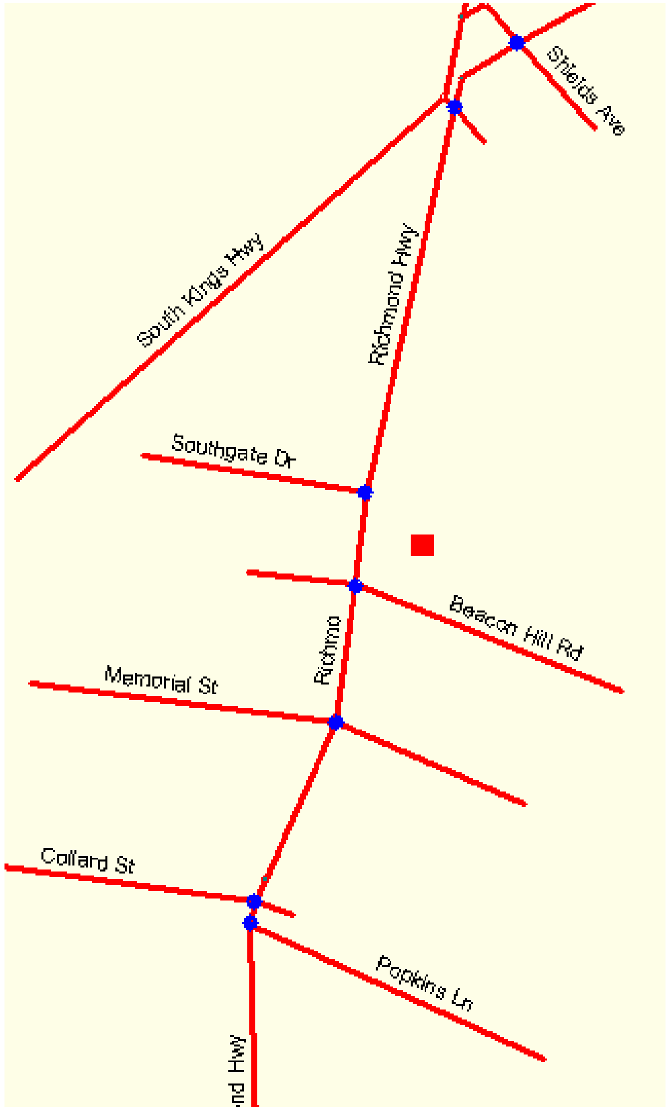


Exhibit B: U.S. Route 1 Test Area



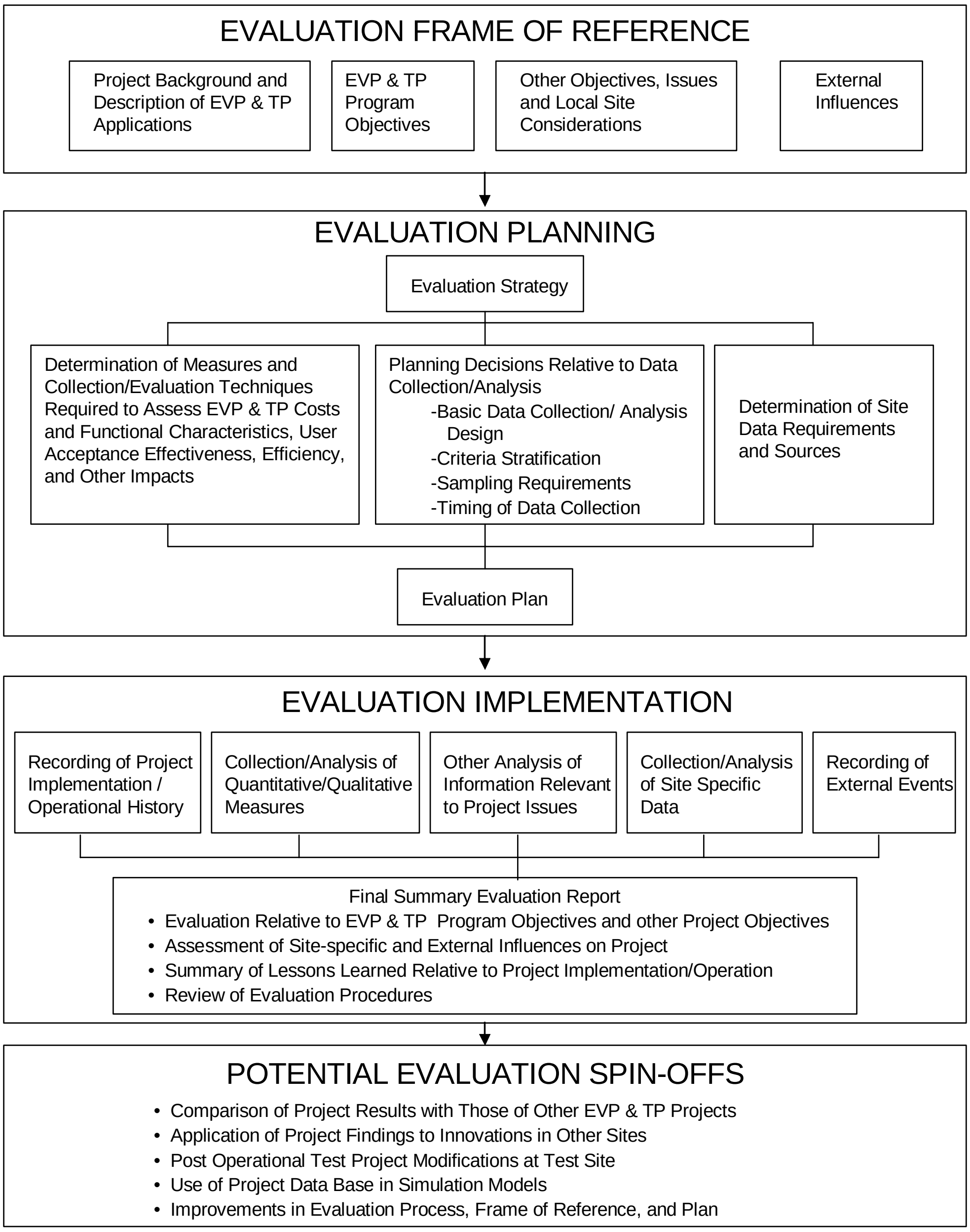
Legend

Fire Station Number 11

Signalized Intersections

Richmond Highway is also U.S. Route 1

Exhibit 11: An Evaluation Process*



* Adapted from APTS FTA Program Guidelines and UMTA(FTA)/SMD Program Evaluation Guidelines

Source:
Casey R., F. and Collura, J., *Advanced Public Transportation Systems: Evaluation Guidelines, Final Report*, Advanced Public Transportation Systems Program, Office of Technical Assistance and Safety, U.S. Department of Transportation, January 1994.

Exhibit 12: Emergency Vehicle Preemption Evaluation Objectives and Measures

Objective	Measures	Data Source
EV Crash Potential	Conflict Point Analysis	1. Video 2. Field Observation
EV Delay	Speed Reduction Stop Time Average speed	1. Video 2. Field Observation
Impact to Other Users	Queue Length	1. Video 2. Average Queue Lengths at Key Intersections

Source: Louisell, C. and Collura, J., A Framework for Evaluation of Preferential Treatment of Emergency and Transit Vehicles at Signalized Intersection, presented at the ITSVA Annual Meeting, June 2002.

Exhibit 13: Transit Priority Evaluation Objectives and Measures

Objective	Measure	Measurement
Bus Service Reliability (transit schedule adherence)	On Time Performance	% of arrivals in on-time window at timepoint(s)
	Time Reliability	Standard deviation of elapsed time between timepoints/ endpoints
	Perceived OTP	Survey measure of rider opinion
	Spacing	Maximum headway measured at timepoint(s)
	Arrival Reliability	Standard deviation of delta (actual time vs. scheduled) at timepoint(s)
Bus Efficiency (transit travel time savings)	Run Time	Elapsed time (mean) between start and end points
	95%-ile RT	95%-ile elapsed time between start and end points
	Trip Time	Weighted passenger time on board/in-vehicle
	Perceived Travel Time	Survey of change in riders' opinions before & after
Other Traffic-Related Impacts	Overall Delay	Delay by [corridor/intersection], [person/vehicle]
	Number of Stops	Stops by [corridor/intersection], [person/vehicle]
	Mainline Travel Time	%-ile/average operating speed
	Cross Street Delay	Maximum/95%-ile delay, average delay
	Fuel Consumption/ Emissions	Model output for corridor, average per vehicle
	Overall System Efficiency	Throughput achieved vehicles per hour, persons per hour
	Intersection Safety	Red light running/accident frequency

Source: Chang J., Collura, J., Rakha, H., and Dion, F., *Evaluation of Service Reliability Impacts of Traffic Signal Priority Strategies for Bus Transit*, paper accepted for publication by the Transportation Research Board, 2003.

Exhibit 14: Emergency Vehicle System Deployments in U.S.

No.	Agencies	Total Signal	EVP	%
1.	Orange County, CA	224	0	0.0
2.	City of Alexandria, VA	224	0	0.0
3.	Town of Vienna, VA	13	0	0.0
4.	Town of Leesburg, VA	20	0	0.0
5.	City of Richmond, VA	430	0	0.0
6.	City of Atlanta, GA	824	2	0.2
7.	City of Dallas, TX	1,200	6	0.5
8.	Texas DOT, TX	5,500	30	0.6
9.	City of Irvine, CA	218	2	0.9
10.	City of Cincinnati, OH	703	7	1.0
11.	Palm Beach County, FL	900	9	1.0
12.	City of Clearwater, FL	145	2	1.4
13.	City of Fairfax, VA	53	1	1.9
14.	Lincoln NDOR, NE	685	13	1.9
15.	VDOT NOVA, VA	869	17	2.0
16.	KY DOT, KY	2,350	50	2.1
17.	City of Virginia Beach, VA	303	7	2.3
18.	Broward County, FL	1,400	43	3.1
19.	Montgomery County, MD	700	25	3.6
20.	City of Wichita, KS	335	13	3.9
21.	Town of Herndon, VA	25	1	4.0
22.	City of Minneapolis, MN	792	35	4.4
23.	Arlington County, VA	225	10	4.4
24.	City of New Orleans, LA	450	22	4.9
25.	City of San Antonia, TX	1,000	50	5.0
26.	Georgia DOT, GA	1,500	83	5.5
27.	City of Forth Worth, TX	560	32	5.7
28.	City of Seattle, WA	900	55	6.1
29.	Forth Worth District, TX	600	40	6.7
30.	City of Seattle, WA	290	20	6.9
31.	West Virginia DOT	1,300	90	6.9

(Exhibit 14 continues to the following page)

No.	Agencies	Total Signal	EVP	%
32.	PA DOT Bridgeville, PA	1,165	88	7.6
33.	County of Henrico, TX	106	10	9.4
34.	City of Milwaukee, WI	700	70	10.0
35.	City of Omaha, NE	575	60	10.4
36.	Dade County, FL	2,409	300	12.5
37.	City of Falls Church, VA	29	4	13.8
38.	City of Arlington, VA	254	42	16.5
39.	City of Hampton, VA	150	25	16.7
40.	City of Amarillo, TX	239	41	17.2
41.	Culpeper District, VA	54	12	22.2
42.	Minnesota DOT, VA	1,200	300	25.0
43.	City of Manassas Park, VA	3	1	33.3
44.	Wisconsin DOT, WI	500	175	35.0
45.	Salem District, VA	150	55	36.7
46.	City of Reno, NV	220	100	45.5
47.	City of Roanoke, VA	132	90	68.2
48.	City of Richardson, TX	97	85	87.6
49.	Washington County, MD	10	9	90.0
50.	City of Plano, TX	130	130	100.0
	Total	**32,861**	**2,262**	**6.9%**
Remarks: More than 90% of the agencies that have deployed EVP have not conducted an evaluation of their deployed system.				

Source: Asmussen, K. et al., “Traffic Signal Preemption Study,” Virginia Department of Transportation, Northern Virginia District Traffic Field Operations, September 1997.