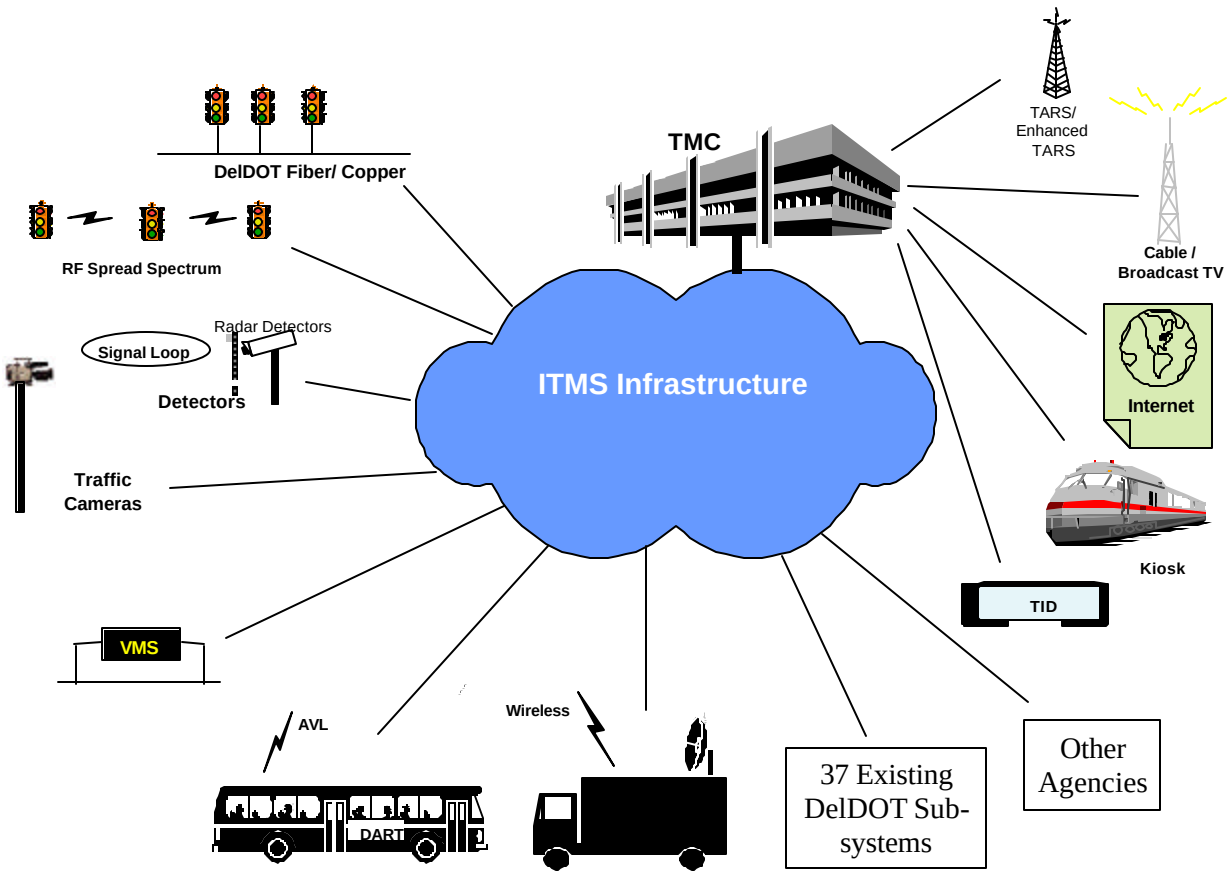
REPORT

Delaware Statewide ITMS Integration - ITS Evaluation Strategy

January 2002



Prepared for:
U.S. Department of Transportation
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1.0 Introduction and Background

1.1 The Delaware Statewide ITMS Integration Case Study

In 2000, the U.S. Congress earmarked funds for selected projects that were assessed as supporting the improvements of transportation efficiency, promoting safety, increasing traffic flow, reducing emissions, improving traveler information, enhancing alternative transportation modes, building on existing intelligent transportation systems (ITS), and promoting tourism. A small number of these projects have been selected for national evaluation. The Delaware Statewide Integrated Transportation Management System (ITMS) being developed by the Delaware Department of Transportation (DelDOT) was among the selected projects.

A team led by SAIC, under direction from the USDOT ITS Joint Programs Office (JPO), was selected to develop and implement a case-study evaluation of ITMS. The following excerpt from the Statement of Work (SOW) for this task defines the objectives of this evaluation:

> *"Case Study/Lesson Learned studies should provide qualitative information to others in the ITS arena to help ensure success of their projects. In particular, the State of Delaware integration evaluation should provide specific information regarding the steps taken to merge Freeway, Arterial, Emergency, and Transit Management systems together. Also, lessons learned regarding how to tie legacy systems to new systems will be reported. Finally, the lessons learned through the use of XML to manage and exchange data is highly desired. The case study should explain to developers how to utilize existing technologies to build a seamless transportation management system. The final report should document both technical and institutional steps regarding how the system was implemented and integrated."*

In other words, this evaluation will provide qualitative information about how the DelDOT ITMS project developed a highly integrated system for managing and sharing transportation data so that future developers of similar systems can benefit from DelDOT's experience. This evaluation will consider both the technical and institutional steps required to implement ITMS, and will focus on the integration of legacy systems and the use of extensible markup language (XML) in ITMS.

What is XML?

XML, or Extensible Markup Language, is a standard for storing structured data. It was originally designed as a method for storing structured document content separately from document formatting, but it is commonly used today as a general-purpose method for exchanging data between applications. While XML frees system developers from defining how to structure messages for transfer between sub-systems, developers must still identify the messages and the content of those messages. The primary advantages of using XML are that it is text-based and self-documenting so that an XML message is easily interpreted by human readers and it is widely supported. The primary disadvantages are that it is wordy and, if security is a concern, is easily interpreted if intercepted.

The Evaluation Strategy presented here was developed to serve as a planning and guidance document as the first major step in a successful evaluation effort. This strategy, based on the general objectives listed in the SOW, identifies specific goals for this evaluation and identifies the methods that will be used to meet those goals. It also provides a high-level schedule and identifies the key milestones for the evaluation. The evaluation itself will begin, following the methodology and schedule described in this evaluation strategy document, and evaluation

progress will be documented in periodic progress reports and interim briefings. The evaluation will result in the production of a Case Study report.

1.2 Delaware's Integrated Transportation Management System

In Delaware, as in most States, the various systems and sub-systems that manage, maintain, analyze, and respond to transportation data reside on many different hardware and software platforms that are connected using a variety of communication systems. One result of reliance on this disparate collection of systems is that developing new systems that rely on information from multiple existing systems is very difficult, requiring the utilization of different communication systems and specialized software and/or hardware for integration.

This difficulty is often a significant impediment to developing new systems that can provide new capabilities by leveraging the wealth of transportation data that is available across the State. When a system, such as a traffic management center (TMC), absolutely requires access to data from several other systems, specialized methods are developed to provide this data. However, these specialized methods are often costly and do little to help make this data available to other systems that could use it. These methods may also do little to help in automating transportation processes because the data may be available to users through separate applications installed at a single user location rather than through a single application accessing separate data sources; in that case, the user is required to review data from several applications in order to identify an "integrated" response rather than having an application help integrate this data and identify responses.

In 1997, DelDOT published the *Delaware Integrated Transportation Management Strategic Plan*, describing a different approach that "incorporates all modes of transportation in Delaware (roadways, transit, rails, ferries, airports, ports, etc.) into a seamless transportation system that enhances the movement of people and goods throughout the State and meets the needs of DelDOT customers." In other words, instead of developing new transportation applications that, as part of the application, integrate data and services as needed, DelDOT is developing an ITMS infrastructure that serves as the common source of transportation data for all applications and provides shared techniques for accessing that data. As depicted in Figure 1, this promises to simplify interactions between both the systems and agencies that rely on transportation data, which should result in long-term costs savings and in the development of novel, new systems that utilize this integrated source for transportation data.

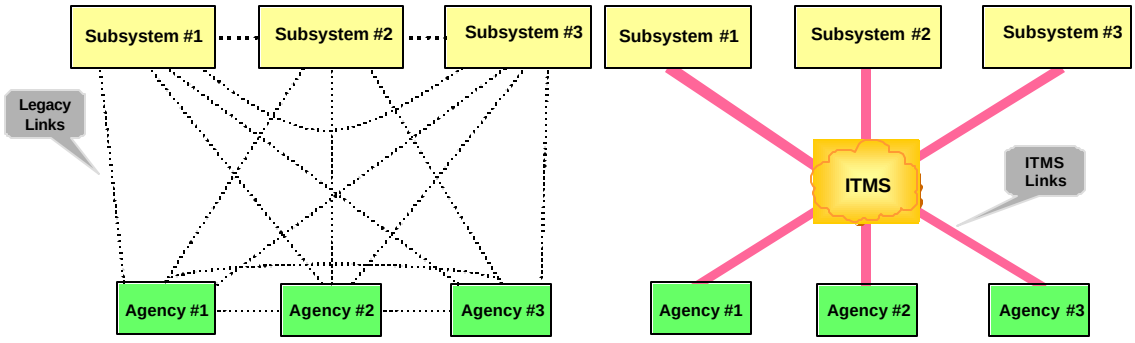

Figure 1. Component Interactions With and Without ITMS

The broad level of integration called for in this strategic plan (see Figure 2), requires design and implementation of a core ITMS infrastructure that provides the communications infrastructure and data hardware and software necessary to collect, process, store, and distribute data from a common data store

using standardized access methods. It also calls for an iterative approach for integrating systems into ITMS.

Delaware began by identifying 675 miles of road that, by including them in ITMS, would generate the greatest benefit to the public, and went on to identify the 250 critical miles of roads among these 675 miles. It is for these sections of road that the initial ITMS implementation is targeted. Delaware also evaluated the different types of transportation data that are related to these sections of roads and the different applications that might use this data, and identified a schedule for integrating different data sources and transportation applications with ITMS.

Delaware could then follow a somewhat generic methodology for integrating a system with ITMS. First, an ITMS communication network was established. To this end, DelDOT extended its existing copper-based communications by installing approximately 61 miles of fiber cable along Delaware roads and providing additional loops to connect State facilities that are located near to this roadway fiber network. This network, which DelDOT continues to expand, connects fixed devices that lie on or near major roads both to each other and to the central ITMS infrastructure. To communicate with mobile devices and devices for which it is not feasible to provide a fiber connection, DelDOT also supports an 821 MHz wireless communication system.

Second, common communication methods must be identified for communicating between devices. DelDOT has selected IP-based protocols and XML as standards for transmitting data between devices.

Third, the system must be connected with the ITMS communication network. This could require both hardware (e.g., to connect a system to the fiber network) and software (e.g., to generate XML-based messages rather than messages in a proprietary format) changes to the existing system, as well as software changes to the ITMS infrastructure so that data from the new system can be processed, stored, and distributed.

Finally, applications must be developed that utilize data from the new system. For example, TMC applications that once relied on direct connections to field devices for traffic data and to adjust signal controllers must be updated to instead rely on the ITMS infrastructure to receive data and adjust controllers.

The Delaware Statewide ITMS Integration project, which is the focus of this evaluation and is the first project to integrate systems with the ITMS infrastructure, will begin the process of integrating the highway system into ITMS by connecting the electronic detection, video monitoring, and traffic signal control systems to the ITMS communication network and the ITMS central control system and operations software. Figure 2 depicts the scope of this project within the framework of the overall ITMS effort.

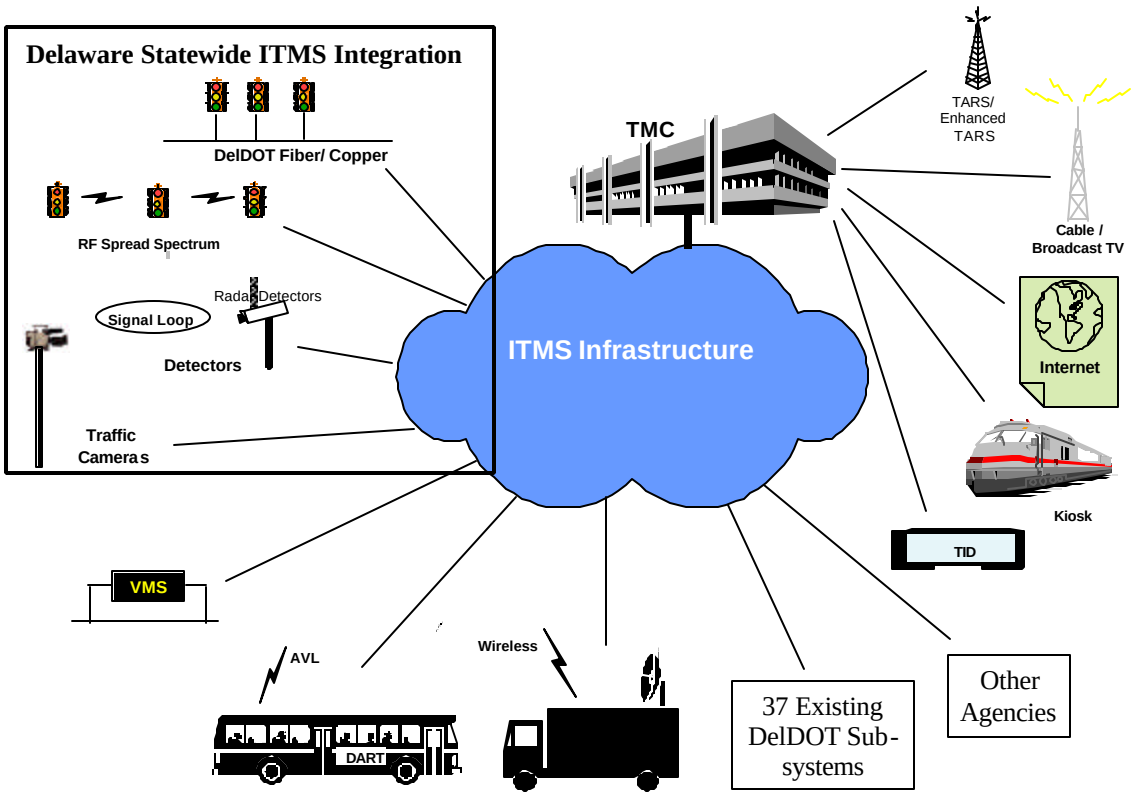

Figure 2. The Delaware Statewide ITMS Integration Project

In this figure, it is seen that the scope of the Delaware Statewide ITMS project is the integration of the electronic detection, video monitoring, and traffic signal systems with the ITMS infrastructure. The following paragraphs describe the groundwork that has already been laid to integrate each of these systems and the additional actions that will be taken as part of this project.

Electronic Detection. Currently, data from electronic traffic detectors are connected to different system-monitoring sites, and the existing TMC allows for separate monitoring of each site. As part of the Delaware Statewide ITMS Integration project, these sites will be connected to the statewide signal system, making the detection data available for adaptive traffic control operations, for storage in a central relational database, and for access by DelDOT's Integraph GIS for display and analysis. All departments within DelDOT will then have access to accurate, up-to-date data regarding traffic volumes, speeds, and occupancies.

Video Monitoring. Currently, video monitoring cameras in urban areas operate over a mixture of private and leased communication networks and are not integrated in terms of control, operations, and monitoring. Separate systems at the TMC are required to control and monitor different video cameras. This project will connect more cameras to the DelDOT fiber network and will begin the process of creating an integrated system to control, operate, and monitor those cameras.

Traffic Signals. Currently, the traffic signal control hardware in urban areas has been upgraded to be compliant with the statewide signal system specifications. Also, the transportation management system at the TMC has migrated to ACTRA, an NT-based tool that provides for adaptive traffic control. During this project, these controllers will be tied to the statewide IP-based communications network. In most cases, this will require installation of field communication equipment to interface between the controllers and the state communications network. In some cases, this will also require installation of additional fiber

and/or copper cable and communications equipment to connect the controllers to the closest link on the existing network.

When this project is completed, traffic data from electronic detection devices and video data from video monitoring cameras will all be accessible through the use of standardized access methods through the ITMS infrastructure, and standard ITMS infrastructure methods can be used to monitor and adjust each traffic signal controller. This functionality serves as a natural complement to the other efforts at DelDOT that will begin to integrate transit and emergency response operations with the ITMS infrastructure, will co-locate TMS, transit, and emergency response activities, and will make data that is managed by the ITMS infrastructure available via the Internet.

2.0 Evaluation Strategy

2.1 Evaluation Objectives

The excerpt from the statement of work quoted in section 1.1 lists the following five general objectives of this evaluation:

- Document the technical and institutional steps required to implement and integrate the system.
- Explain how to utilize existing technologies to build a seamless transportation management system.
- Provide lessons learned in using XML to manage and exchange data.
- Provide specific information on the steps taken to merge Freeway, Arterial, Emergency, and Transit Management systems together.
- Provide lessons learned on how to integrate legacy systems into a new system.

The following five sections provide a more detailed description of each of these objectives, lists the evaluation work product(s) that will be generated to meet these objectives, and describes the evaluation approach that will be used to generate these work products.

2.1.1 The Technical And Institutional Steps Required to Implement and Integrate the System

Integrating the electronic detection, video monitoring, and traffic signals into the ITMS infrastructure requires that DelDOT successfully complete a number of technical and institutional steps, and documenting these steps can help other States implement similar integration efforts. In fact, as described in section 1.2, each sub-system integration effort involves a similar set of activities to establish a communication network, connect the sub-system to this network, and develop applications to handle interactions between the sub-system and the network. Thus, documenting the technical and institutional steps required for this project can serve not only to help other States integrate these specific types of devices, but can also serve as a template for integrating other types of systems. This evaluation will generate several work products intended to document the steps taken by DelDOT and the lessons learned during this integration.

The primary work products will be three annotated, logical timelines, one for each type of field device, which describes the technical steps taken to integrate these devices with the ITMS infrastructure. The timeline will list each of the key steps in the integration process and the approximate date when that step was completed, and will also highlight the occurrence of key events that resulted in lessons learned during this integration project. In addition, the information in these timelines will be synthesized to produce a flowchart indicating the general steps required for this type of integration. Interviews with DelDOT project management staff early in the evaluation will provide the basic timelines and points of contact for follow-up interviews. Periodic follow-up interviews during the course of the project will identify steps that were omitted from the initial timelines, the completion dates of steps, and lessons learned as they occur. We expect to use email and fax to facilitate the follow-up interviews by letting the contacts mark-up the latest version of the timelines with any changes that have occurred.

The other work product associated with this objective will be a matrix of institutional responsibilities that describes the various organizations within DelDOT that were responsible for specific implementation steps and the role they played in the integration. When special accommodations (e.g., cost sharing between organizations) were required to help facilitate appropriate institutional cooperation, these will be documented as lessons learned associated with this matrix. Once again, interviews with project management staff and follow-up interviews will serve as the primary methods for gathering this information.

2.1.2 The Use of Existing Technologies to Build a Seamless Transportation Management System

One of the questions that must be considered in any systems engineering project is whether to re-use, buy, or build the various components that comprise the system. Re-using or buying a component that provides the required functionality can have many advantages: costs may be lower and experience using the component already exists. Most importantly is the overall decrease in both project schedule and cost uncertainty that comes with replacing a large design-build-and-integrate project step with a purchase-and-integrate step.

In developing software systems, however, there can be unexpected long-term costs to re-using or buying a component. The high-level design information that is commonly available when a buy-or-build decision is made may not reveal incompatibilities or limitations of the purchased component that become apparent later in the development cycle, or changing requirements force changes that a purchased component simply does not support. Retrofitting an existing component to meet requirements for which that component was not originally designed can be more difficult than simply rebuilding the component. Information gained on the costs and benefits of using existing technologies can be a valuable tool helping other system designers better utilize existing technologies.

The primary work products used to meet this objective will be architecture diagrams that describe each of the system components (both hardware and software) that are used to connect the field devices with the ITMS infrastructure. Each component will be categorized as existing, purchased, modified, or built and the rationale for this decision will be documented. These architecture diagrams will also serve as the basis for documenting lessons learned in working with the individual components, and information about reusable components developed for the Delaware Statewide ITMS Integration project will be documented as lessons learned. As with the technical and institutional steps, interviews with the technical staff involved in the integration activities will be the primary method used to gather this information.

2.1.3 The Use of XML to Manage and Exchange Data

One of the key elements of the Delaware Statewide ITMS Integration project is the use of XML as the common method for exchanging information between the various systems and components that comprise ITMS. The use of XML has many potential advantages over the hodge-podge collection of data exchange methods traditionally used – XML can contain complex data structures, tools already exist for creating and reviewing XML data (which can help when developing and debugging XML-based data exchanges), tools already exist for managing XML-based data exchanges between components, XML data formats can be easily shared through the use of templates (e.g., document type definitions [DTDs] or XML Schemas), XML is compatible with Web-based development, and XML exchanges can pass through most firewalls. However, there are some disadvantages (e.g., XML is very "wordy" and, because it is plain-text and self-documenting, can be easily deciphered if intercepted) and some uncertainties (e.g., most ITS data exchange standards are not expressed in XML, XML specifies a data format but not an exchange mechanism for transmitting data between components). Documenting how XML was used in the ITMS project can help future designers better understand the advantages of using XML and can remove some of the uncertainties by providing an existing implementation that has already resolved them.

The architecture diagrams described in the previous section will serve as the first step in describing the use of XML. Each connection between the components represented in these diagrams indicates a set of messages that are transmitted between these components, and the diagrams will indicate which of these transmission paths handle XML messages. Moreover, each component will be characterized according to whether it produces, consumes, translates, or transmits XML messages that pass through it. These diagrams, derived from the DelDOT technical documentation and confirmed by their technical staff, will provide a high-level overview of how XML was used in the ITMS integration project.

This high-level information will be complemented by more detailed information that lists the messages that are produced and consumed by each component and the types of translations each component

performs. Most of this information is expected to be available in the form of Unified Modeling Language diagrams developed by DelDOT and its contractors during system development. Even more detailed information will be presented in the form of either DTDs or XML Schemas that will be provided for a few selected messages. Finally, documenting the trail taken by a few specific messages as they pass between components and are processed by components will complete the picture of XML usage in the DelDOT project.

Although the above work products will help describe how to use XML to manage and exchange data, they do not address several issues that are key to using XML in ITS applications. Each of the following issues will be addressed by interviewing DelDOT to identify the steps taken to address each issue and documenting the results of those interviews.

- Compatibility with ITS standards. Many ITS standards have already been developed to help standardize interactions between the transportation devices that are being integrated in the Delaware Statewide ITMS Integration project. However, most ITS message standards are not expressed in XML. The evaluation will describe the steps DelDOT took to ensure that inter-component messages implemented in this integration project are consistent with applicable ITS standards.

- Security. XML is a self-documenting, text-based messaging system, which creates the opportunity for unintended recipients to intercept or impersonate inter-component communications. Obviously, the potential for traffic signal devices to receive adulterated messages that could modify their signaling behavior is unacceptable, and DelDOT is implementing a security system to deal with this threat. The evaluation will describe the steps DelDOT is taking to ensure the security of inter-component messaging in this integration project.

- Tools. Many software tools are available for creating and parsing XML text and for managing XML data. The evaluation will describe the tools that DelDOT selected to help facilitate the use of XML in the integration project.

The information for these descriptions will come from the technical documents reviewed by the evaluators and from interviews with DelDOT staff.

2.1.4 The Steps Taken to Merge Freeway, Arterial, Emergency, and Transit Management Systems Together

The overall ITMS effort aims to integrate data across multiple systems at DelDOT, including freeway, arterial, emergency, and transit management systems. However, the Delaware Statewide ITMS Integration project has the more limited scope of integrating electronic detection, video monitoring, and traffic signals with the ITMS infrastructure. This integration does involve integration of devices positioned along both freeway and arterial roadways, and the evaluation will document the approach DelDOT used to address any institutional barriers that may have been encountered during this integration project.

This integration does not involve direct integration of emergency and transit management systems; the integration of these systems is part of other projects currently underway at DelDOT. However, the evaluators recognize the opportunity to gather information about these additional integration activities at DelDOT simultaneously with gathering information about the Delaware Statewide ITMS Integration project and, to the extent that this information can be obtained without affecting the primary objectives of this evaluation and without duplicating the effort of other evaluations, the evaluators will document information about these other integration activities. The work product used to document this portion of the evaluation will be lessons learned that are identified during interviews with DelDOT staff.

2.1.5 The Integration of Legacy Systems Into a New System

The Delaware Statewide ITMS Integration Project is being implemented in an environment that includes both a large number of existing systems and several new systems under simultaneous development. Moreover, this project involves transportation data that is critical to DelDOT's ability to effectively manage traffic operations, which requires that the transition to the new, integrated techniques occur in a fail-safe manner that can rely on the older, legacy systems in case errors are discovered in the newly developed systems. (Alternately, DelDOT may rely on a phased migration to the new systems so that a failure will affect only an acceptably small part of the overall system.) Also, additional legacy systems exist at DelDOT that, even though they will not interact directly with the field devices integrated during this project, will interact with the data generated by these devices and stored in the ITMS infrastructure databases. This evaluation will consider both types of interactions with legacy systems and will document the steps DelDOT will take to ensure a smooth transition to the new system and continued smooth interactions between the new system and legacy systems that remain.

The evaluation team will generate three evaluation products to document issues related to integrating with legacy systems. First, the team will generate interaction matrices that identify the legacy systems that rely on data from the affected electronic detector, video monitor, and traffic signal devices. Then, the team will select one of those legacy systems and will provide a more detailed description of the steps taken by DelDOT to ensure continued operation of that legacy system after these devices have been integrated with the ITMS infrastructure. The team will also follow-up with DelDOT staff to identify lessons learned regarding any of these interactions. Finally, the team will generate a checklist of factors to consider when transitioning to a new system; this checklist will document many of the types of failures that could occur during this transition and the steps DelDOT took to mitigate against negative consequences of a failure that might occur. Each of these products will be derived from information gathered during interviews with DelDOT staff and contractors.

3.0 Evaluation Management Plan

3.1 Evaluation Organization

The management organization for the Delaware Statewide ITMS Integration evaluation effort is presented in Table 1. Personnel of Science Applications International Corporation (SAIC), supported by personnel of Daniel Consultants, Inc. (DCI) are performing this evaluation. The project team reports directly to Dr. Joseph Peters of the USDOT.

Table 1. Management Organization

Role	Personnel
FHWA Evaluation Oversight	Joseph Peters – FHWA/JPO Pierre Youssef – Mitretek Systems
Evaluation Team Management	Mark Carter – SAIC (National Evaluation Manager) Robert Haas – SAIC (Evaluation Coordinator)
Analysis & Support	Kelly Pecheux – SAIC (Research Engineer) Tanya King – DCI (Transportation Engineer) Tom Tran – DCI (Transportation Engineer)

3.2 Overview of Evaluation Deliverables

The technical reports to be developed from this evaluation will be as follows:

Evaluation Strategy Report. This document is the evaluation strategy report for this evaluation, which addresses comments received on the draft evaluation strategy report.

Evaluation Draft Report. This draft version of the evaluation report will be delivered for review and comment. This draft of the comprehensive final report will document both the methodology and the detailed results of the evaluation, including the work products listed in this evaluation strategy. An executive summary included in the report will summarize the results of the evaluation. Comments received regarding this draft report will be addressed in the final report.

Evaluation Final Report. This final evaluation report will be the revised version of the evaluation draft report described in the previous paragraph.

3.3 Schedule

The evaluation schedule is provided in Table 2. The major deliverables in this schedule are described in the previous section, and the remaining items in the schedule are project milestones with their anticipated completion dates.

Table 2. Evaluation Schedule

Date	Milestone or Deliverable
Fall 2001	Kickoff Meeting / Initial Data Collection Activities
January 24, 2002	Draft Evaluation Strategy (deliverable)
March 1, 2002	Interim Briefing at PAWG
March 2002	Detailed Test Plan
March 28, 2003	Draft Final Report (deliverable)
May 23, 2003	Final Report (deliverable)

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EDL Document No.: 13683