CALTRANS – DIVISION OF TRAFFIC OPERATIONS

EXAMPLE - TECHNICAL AGREEMENT PROPOSAL – INTEGRATION THROUGH LAUNCH

CONNECTED CORRIDORS

I-210 PILOT IMPLEMENTATION – SYSTEM INTEGRATION, SYSTEM DEPLOYMENT AND OPERATIONAL SUPPORT

Proposed By:

PARTNERS FOR ADVANCED TRANSPORTATION TECHNOLOGY

HOW TO USE THIS DOCUMENT

Over the last 30 years, the California Department of Transportation (Caltrans) has partnered with California PATH (Partners for Advanced Transportation Technology) on numerous transportation and technology projects.

This latest effort, Connected Corridors, is an integral component of Caltrans' plan to shift its focus from capacity building to transportation system management and operations (TSMO). Connected Corridors seeks to utilize new information and communications technologies to bring together vehicles, infrastructure, and people. Known traffic management strategies, such as ramp metering and signal synchronization will be combined with innovative practices including better integrated intermodal operations, real-time decision support systems, and dynamic traffic-responsive route guidance.

The Connected Corridors program is starting with a Pilot located on the I-210 corridor in Los Angeles County. The I-210 Pilot is focused on improving corridor level transportation system operations and management, specifically during incidents and events. Since 2013, Caltrans and PATH have actively engaged local stakeholders including LA Metro, LA County, and the cities of Pasadena, Arcadia, Duarte, and Monrovia.

In addition to implementing transportation management for the I-210 corridor, another crucial goal for the I-210 Pilot is creating document templates and software tools for other corridors and districts to use. To achieve this goal, the Connected Corridors team has invested a significant amount of time into documenting our process and making this information available to Caltrans Districts and other interested parties.

We have created this ICM Proposal Example as an example for other Districts and parties to review the tasks that we have found critical from the start of the Pilot through implementation. The ICM Technical Agreement found in this example is an excerpt from a proposal prepared by PATH for the Connected Corridors Program. This ICM Proposal Example has been broken into two parts for easier use. Part 1 includes Tracks A through D which covers project management, outreach, systems engineering, and AMS (analysis, modeling, and simulation). The amount of AMS the I-210 Pilot team did was more detailed than may be required for your project. Please note this as a potential difference for your project. Part 2 includes two additional tracks, Tracks E and F, which cover integration and deployment and operational support.

When beginning a TSMO project, we recommend you consider the following steps:

- **Needs Assessment** – Complete an inventory of the corridor or project area. What assets does the corridor have? Who are the key stakeholders? What are the key systems and transportation components? What is the corridor missing? What are the issues most impacting the transportation system? The I-210 Pilot team considered multiple corridors before settling on the I-210 corridor. In addition to strong stakeholder relationships in the region, LA Metro was in the process of extending one of their light rail lines through the area. Frequent incidents causing congestion, supportive stakeholders, and multiple adjacent arterials made the I-210 corridor standout to the project team.
- **Project Management** – Strong project management is required to work with the numerous vendors and stakeholders involved. Project Champions are also critical to support the mission of the project and share their excitement with the team. Management of an ICM implementation is a full time job. It includes both standard project management activities and leadership. The Project Manager is the person who is ultimately responsible for maintaining and growing the vision, nurturing the enthusiasm of the project champions, coordinating the funding, ensuring the right resources are available, managing stakeholder relationships, and doing whatever needs to be done to ensure the project is delivered. The challenge here

is to find a person who understands their role with Caltrans, who understands that while Caltrans may be funding and leading the effort, they are new to this type of cooperative leadership, are often unable to assign a full time project manager on their side, and are currently experiencing a large number of retirements. These realities require that the PM be willing to engage in forthright conversations that are not always comfortable. This is also true with the vendors and consultants who are an integral and required part of the success of the project. Thus, the selected PM should be a person/organization willing to take risks to ensure the success of the project, provide a long-term commitment, and in cooperation with Caltrans, truly assume the leadership mantle.

- **Project Planning/Concept of Operations** – Prepare the Systems Engineering Management Plan and a high-level Concept of Operations with input from stakeholders to serve as the foundation for the project. Start building a stakeholder team and develop a project vision with clear objectives that all stakeholders can support. Develop a Project Charter early in the planning process and ensure stakeholders buy-in to the project's vision and level of effort required of them. The Concept of Operations should include the information learned from the needs assessment, as well as the project's vision and objectives. Funding may still be unknown, so project specifics may be somewhat lacking. The more stakeholders you can involve at this point, the better. The I-210 Pilot's Project Charter was signed by eleven agencies, with the primary purpose of getting them involved for the development of the Pilot. Ultimately, the MOU will be signed by only the stakeholders that have equipment connected to the ICM system, about seven agencies for the I-210 Pilot.
- **Apply for Funding** – Use the high-level concept of operations and your stakeholder team to apply for local, regional, state and/or federal funding. Caltrans supported the I-210 Pilot with SHOPP funding, in addition to applying for regional and federal grants. Caltrans was awarded funding from LA Metro, a key project stakeholder, for the arterial improvements. The management of this local funding by Caltrans was precedent setting and showed Caltrans commitment to the stakeholders and the I-210 Pilot's success.
- **AMS** – Analysis, Modeling, and Simulation is needed to ensure the success of the project. Early on, AMS uses the initial corridor inventory to determine what new ITS elements are needed and on which routes these elements will be installed. Later on, AMS helps with the development of response plans and assessing the benefits after launch. A significant amount of time continues to be spent on improving and refining the I-210 corridor model. The model is being used to develop response plans, signal timing changes and other possible improvements. Once deployed, the model will continue to play a vital role in the recommendation of new response plans and in justifying further corridor improvements.
- **System Definition** – Refine the Concept of Operations document and develop the System Requirements, and High-level system architecture. Obtain stakeholder input at every step and begin to pursue a Memorandum of Understanding for system integration and operations. Caltrans and PATH held numerous meetings with stakeholders to develop the system requirements including specific job skills and tasks that were determined necessary to operate and maintain the system. Many of these job skills were new to Caltrans. Having the system requirements early in the process gives everyone time to allocate the necessary resources, including staffing to meet those requirements. The MOU process often requires educating additional stakeholders about the project and refining everyone's agreed upon roles and responsibilities. Project leaders need to find the balance between starting the process early, but having enough of the details of the system and operations to execute a meaningful MOU.
- **System Design and Development** – Understand the components of your system implementation. Utilize the documentation and software available from the I-210 Pilot. The I-210 Pilot software systems were developed specifically to be reused in new corridors. The decision to use the Cloud, build standardized TMDD based center to center communications software, develop a reusable data hub and decision

support system, and to prequalify Kapsch, Parsons, and Telegra as suitable vendors was made so that future TSMO projects could be implemented faster and more efficiently.

- **System Integration** – Test the system components as they are developed. As systems are acquired and tested, integrate them to prepare for launch. Revise requirements and design documents as needed. Extensive testing was completed for every new or upgraded system within the I-210 Pilot architecture to ensure a successful launch. Successfully integrating the stakeholders' systems to better respond to incidents as a unified team is the core purpose of the I-210 Pilot.
- **Deployment** – Begin operating the system in the live environment. Continue to work with the stakeholder team to identify issues and resolve problems quickly. Evaluate the systems performance and modify as necessary. We are preparing to launch the I-210 Pilot and plan to devote ongoing resources to continual improvement of the system.

The above summary is a very condensed version of the Systems Engineering process and the steps the Connected Corridors team considers to be very important. The Connected Corridors website (https://connected-corridors.berkeley.edu/) contains a wealth of information related to the Systems Engineering process and all of the SE documents we've generated thus far for the I-210 Pilot. We encourage other districts and agencies to review our process and use it as a guide.

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FIGURES

WORK PLAN

The Connected Corridors project's work plan is divided up into six tracks. Each track corresponds to a major theme of the Connected Corridors program and is comprised of a collection of work packages. The work packages are the basic project units that will result in major deliverables.

The first four project tracks are covered in Part 1 of the proposal example. The last two tracks are covered in this document, Part 2.

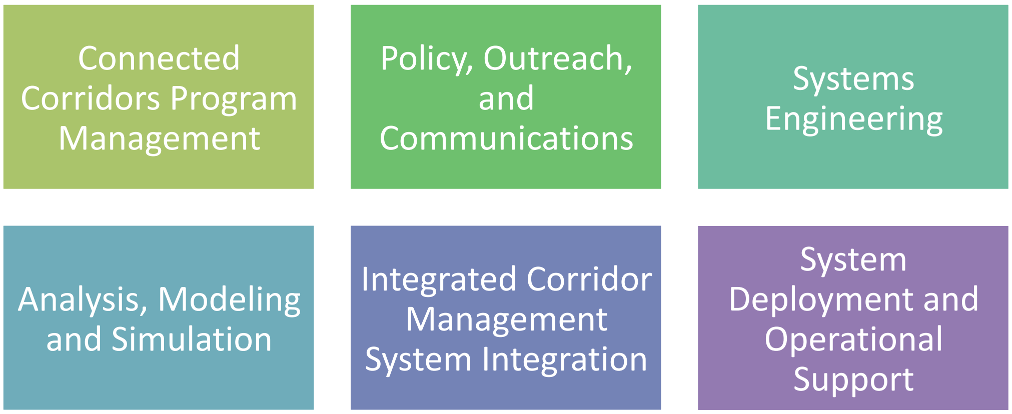

Figure 1 - The Six Tracks of the Connected Corridors Project

The project tracks this example document includes are:

E. ICM System Integration: The generation of system specifications, the identification and sourcing of system components, the definition of interfaces and the technical management needed to assemble the components into a working system
F. System Deployment and Operational Support: Management of system deployment. Support in resolving both organizational and technical issues

TRACK E - ICM SYSTEM INTEGRATION MANAGEMENT

Integrated Corridor Management involves two systems. One is a system of people, organizations, and government. They must work together on common agreements describing how traffic will be managed within a multi-jurisdictional corridor. The other is a system of hardware, data, communications and software. This system, which is really a "system of systems," is used to gather data, choose a traffic management strategy, and then modify traffic control elements in order to implement that strategy.

The exact components and functionality of this system will be defined in various documents generated through the system engineering process. However, it is likely that the final specifications will contain the generic components shown in Figure 2.

If we look at each ring of the Connected Corridors System Component Diagram, these components include:

1) *Hardware*: Sensors for gathering traffic data and controllers for implementing traffic strategies.
2) *Traffic Management Centers:* For example, centers operated by Caltrans D7, LA County, the City of Pasadena, and the City of Arcadia.
3) *Communication Networks:* Methods for transferring data from each TMC to a central decision-making location.
4) *ICM System Software:* Two software layers providing basic ICM functions, such as asset inventory, data storage, and incident characterization.
5) *DSS Supporting Data:* A database providing a synthesis of all data from the surrounding layers in real time for use by the core Decision Support component.
6) *Decision Support:* The system's core component, which will utilize data and guidelines to suggest traffic management strategies in response to incidents and events.

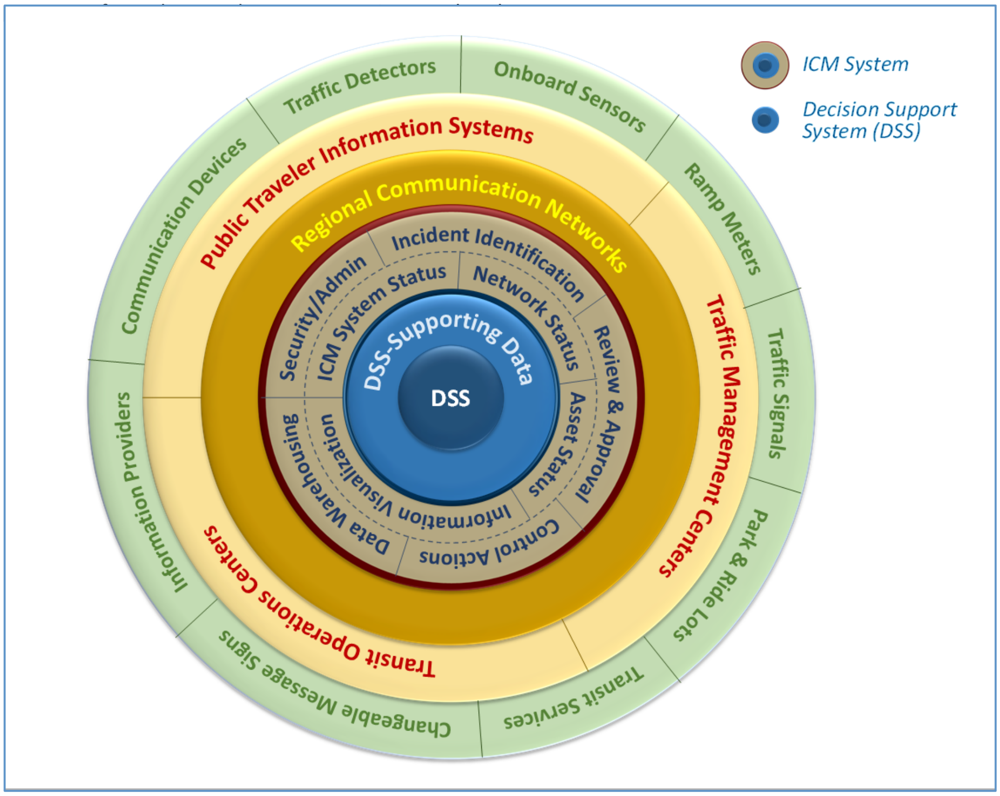

Figure 2 – Connected Corridors Generic System Components

Figure 3 – I-210 System Components

Figure 3 expands the first two rings of Figure 2 to show, specifically for the I-210 Corridor, the various TMCs, the systems they contain, and the data and hardware they are responsible for.

These pictures taken together illustrate several points:

1) The complexity of the system
2) The decentralized nature of the system
3) The importance of institutional and political agreements in ensuring each of the TMCs provide the data and functionality required for the core functions
4) The complexity of the regional communication networks
5) The challenges faced by a systems integrator

This integration management task is responsible for ensuring all of the system components shown in these two diagrams:

1) Exist
2) Work appropriately
3) Communicate correctly
4) In concert, accomplish desired Integrated Corridor Management functions
5) Are as reusable as is practical in other corridors and Caltrans' districts

Importantly, this task does not require the project team itself to build out the system. No one organization controls all of the identified subsystems. As such, the funding for this contract is not meant to encompass the creation of the entire system from scratch. This task is about ensuring that each organization knows what is needed, is provided integration guidance, and is provided with system test results to help ensure the system components it is responsible for work correctly.

A note on Caltrans sourced and owned software: much of the system defined by this track will not be owned or operated by Caltrans. Of the outer layers, Caltrans is only directly responsible for the ATMS and the sensors and controllers that are part of the freeways, highways, and arterials directly managed by Caltrans. With regard to the ICM System Rings, it is not yet clear who will own or be responsible for the illustrated functions, although it is highly likely that Caltrans will be responsible for some of them. The two innermost rings, DSS-Supporting Data and DSS, will be owned and operated by Caltrans.

Pursuant to this, PATH cannot be directly responsible for work that is not managed by PATH and is performed by others not funded from the PATH contract. For example, Caltrans has indicated that updates will be provided to their signal control system, Metro is working on an asset management system, and Pasadena is discussing updating its interfaces to the regional communication network. PATH anticipates these will occur, however PATH cannot be held responsible for these components if, after due diligence and effort from PATH, these organizations choose not to participate in the Connected Corridors program.

Every deliverable in this integration task requires the cooperation of stakeholders. Without cooperation in understanding the currently available subsystems, in planning for upgrades, and in performing upgrades, PATH cannot succeed at delivering a fully functional I-210 Integrated Corridor Management solution.

The subtasks within this task are:

A1: System Definition
A2: Data Definition
A3: Gap Analysis Resolution
A4: Managing the Procurement Process
A5: System Testing
A6: Implementation Management

SYSTEM DEFINITION

Each entry in Diagram 10 must be defined and then mapped to existing systems. Missing pieces will be identified. These are complex tasks as there are considerable constraints placed on the final implementation. These include:

1) Funding
2) Funding schedules
3) Use of existing systems
4) Different design philosophies
5) Emergent challenges related to the complexity of both the technical and organizational structures

The subtasks defined within this task are:

1) Definition of subcomponents
2) Inventory of current environment
3) Gap Analysis

DEFINITION OF SUBCOMPONENTS

In this task, the project team will first identify the priority and level of quality required for each of the entries in Figure 2. Once this is done, the priority components in the outer rings will be defined. For the components in the inner rings, the project team will work closely with the systems engineering team in the definition of those components.

Deliverables

1) Prioritized list of components
2) Definitions of those components

INVENTORY OF CURRENT ENVIRONMENT

Once the components are identified, the existing systems within the corridor will be inventoried and described. This task will involve gathering information on current systems through documentation, stakeholder interviews, working with the systems, and vendor interactions.

Deliverables

1) An inventory of current system components
2) A definition of these components sufficient for Gap Analysis

GAP ANALYSIS

Our system will be comprised of:

1) Existing components
2) Existing components requiring upgrades
3) Components that need to be acquired

Understanding which functions fall into each category is an essential step in creating the system. Identifying the missing functions and components is called gap analysis.

Deliverables

1) A Gap analysis for the I-210 Corridor

DATA DEFINITION

Data will be used extensively within and among all components of the system. This task focuses on the data provided to the Communications Ring from the outer rings and the data delivered back to it from the inner rings.

Current data exchange systems exist within the corridor. These are IEN and RIITS. It is likely that the only practical method of exchanging data will need to involve these data exchange systems. The effort required to define and implement totally new data exchange mechanisms would be cost and time prohibitive.

Subtasks within this task are:

1) Data Definition
2) Data Format
3) Data Exchange Mechanisms
4) Gap Analysis of Existing Data

DATA DEFINITION

In this task, the project team will identify all the data needed to enable an Integrated Corridor Management System. We will work with both the Systems Engineering team and the DSS team in doing this.

Deliverables

1) A Data Dictionary – Note that this is now available from Caltrans/PATH

DATA FORMAT

In this task, the project team will extend the data dictionary to identify the format of the data required for the ICM system.

Deliverables

1) A Data Dictionary with formats– Note that this is now available from Caltrans/PATH

DATA EXCHANGE MECHANISMS

In this task, the project team will define the data exchange mechanisms (Web Services, XML, etc) needed to exchange data with the central communications rings.

Deliverables

1) Data Exchange formats– Note that this is now available from Caltrans/PATH

GAP ANALYSIS

Once existing data is defined, we will determine what changes need to occur to implement our ICM system.

Deliverables

1) A data focused gap analysis

GAP ANALYSIS RESOLUTION

Once the data and functionality gaps are identified, the team will work with the stakeholders to determine what gaps must be filled and how to fill those gaps.

The subtasks are:

1) Determine gap resolution
2) Determine procurement (gap filling) methods

DETERMINE GAP RESOLUTIONS

It will not be possible to fill all gaps. Some may be managed by redefining the specifications, removing requirements, or postponing implementation dates.

Deliverables

1) Gap Resolution Determination

DETERMINE METHODS FOR FILLING ESSENTIAL GAPS

For gaps that cannot be filled through redefinition, we must find a procurement method. These include:

1) Buy
2) Borrow
3) Be Given
4) Build

Deliverables

1) A procurement method for each essential gap

MANAGING THE PROCUREMENT PROCESS

Once the gaps have been identified and a determination made on how to fill these gaps, multiple procurement efforts must commence. The PATH contract does not manage all of these, as many of them will need to be done by the stakeholders. Still, managing and reviewing the procurement processes is important. In addition, communications with the Connected Corridors Steering Committee on funding needs will likely be required.

The subtasks within this task are:

1) Ensure all procurement processes are ongoing
2) Perform internal procurements
3) Manage political challenges of multiple procurements

ENUSRE ALL PROCUREMENTS PROCESSES ARE ONGOING

In this task, the project team will first ensure the various stakeholders have what is needed to get procurements ready, answer questions along the way and monitor status.

Deliverables

1) Procurements underway
2) Status on Procurements

PERFORM INTERNAL PROCUREMENTS

For a number of items, it will be determined that PATH will manage either the building of the required functionality or the procurement of the functions. These internal procurements will be managed by this track.

Deliverables

1) Internal procurement management
2) Delivery of internal procurements

MANAGE POLITICAL CHALLENGES OF PROCUREMENT

With such a large project, vendor and stakeholder scrutiny is high. There are often subtle political pressures or questions raised on the fairness of the procurement process. These need to be managed.

Deliverables

1) A procurement process that does not run afoul of any political or legal challenges

SYSTEM TEST MANAGEMENT

As the "system of systems" is assembled, system level testing will be required. This testing needs to be managed by the project team associated with this track. The test and acceptance documents for subsystems will be the responsibility of each stakeholder/system owner.

The systems engineering team will be involved in writing the test and acceptance plans. This track will be responsible for ensuring these tests are carried out, recording any issues, and resolving those issues.

The subtasks within this task are:

1) Define the systems tests
2) Manage the execution of the tests
3) Resolve issues found in the tests

DEFINE THE SYSTEM TESTS

Once the requirements are finalized and the high level design started, it is possible to start specifying the system tests. This activity is shared with the system engineering team. However the actual test cases themselves are a deliverable from this track.

Deliverables

1) System Test Cases

MANAGE THE EXECUTION OF THE TESTS

System tests will require actions covering numerous system components at once. Each manager of the subcomponents of the system will be responsible for executing their part of the larger test. This track will manage the overall testing, ensuring each subsystem/stakeholder is doing what is needed.

This subtask is also responsible for recording issues found during the tests.

Deliverables

1) Successfully running system tests
2) Recording and tracking of issues

ISSUES RESOLUTION

As the system tests are run, noncompliance issues will arise. These issues may be in the tests/data themselves or in the subsystems. Once an issue is identified, this track will be responsible for the resolution of the issue either through:

1) Modifications to the tests/test data
2) Modifications to the subsystems – This is the responsibility of the subsystem stakeholders
3) Determining that this test is not appropriate or needed and removing the test

Deliverables

1) Resolution of system test issues

IMPLEMENTATION MANAGEMENT

Ensuring that the definition, procurement, implementation, and test of this complex system occurs on time and in budget is arguably the most complex technical requirement of the Connected Corridors Program. Not only does the architecture need to function within the Los Angeles D7 ITS architecture, but it must be designed to work in other districts to the degree possible.

The components of the system are being provided by many different organizations with different cultures and priorities. Ensuring that the overall architectural vision morphs when it needs to and stays strong when it must is a significant management challenge. This challenge is not found in the management of any one subsystem, data element, or test case. It is found in the sum of the parts. The system should be designed to ensure reliability and maintainability within what is sure to be a dynamic development process.

This will require trading off between technical, organizational, political and funding constraints. Stakeholders will not always be in agreement nor fully cognizant of the possible ramifications of certain decisions. Thus, this subtask is focused on ensuring the overall system works and, while every previous subtask is essential to this effort, the summations of those tasks do not in themselves guarantee success.

The subtasks within this task are:

1) Develop Overall Architectural Vision
2) Project Management
3) Risk Management
4) Education

ARCHITECURAL VISION

An architectural vision lays the groundwork for any number of implementation decisions. The vision answers questions related to how the system will work to ensure the subcomponents are a useful part of the larger system. Figure 3 is part of the architectural vision. It must be refined and developed. It is possible there are subsystems that are not yet identified.

Examples of questions to answer include:

- What standards will be used throughout the system? This includes standards for data, data exchange, hardware, software and shared subsystems.
- How would transactions be logged across systems?
- How and when would error messages propagate from a traffic signal controller to the decision support system?

Deliverables

1) An architectural vision
2) The identification of standards

PROJECT MANAGEMENT

Synchronizing so many different development and procurement processes requires good project and people management practices and skills.

Deliverables

1) Schedules, budgets and organization charts
2) Ongoing communication with stakeholders and vendors

RISK MANAGEMENT

Many large risks exist in this track. With so many subsystems there are many opportunities for failure of software, hardware, funding, political will, and vision. These risks must be identified and managed. This will be done in concert with the outreach and systems engineering team.

Deliverables

1) Risk Identification
2) Risk Mitigation

EDUCATION

As we define our "system of systems" the technology and engineering disciplines required will likely not be understood in detail by many of the stakeholders. Without understanding, it can be difficult to gauge the effects of decisions and to provide needed support for difficult decisions. Education on possibilities, technologies, and impacts is needed to ensure success, reduce risk, and enable stakeholders to participate fully.

Deliverables

1) Systems related educational outreach

TRACK F - DEPLOYMENT AND OPERATIONAL SUPPORT

The most visible part of the Connected Corridors project will be the deployment of several advanced transportation management concepts on the I-210 corridor. The I-210 Pilot will be a capstone achievement that sets the direction for the future of the Connected Corridors program.

Deployment functions are shared with several tracks: System Engineering will develop the deployment requirements, the AMS will provide early evaluations of potential operational benefits, and the System Integration effort will be responsible for initial testing and in assisting with problem resolution.

It is important to note that this contract does not cover responsibility for operation of the corridor management system. System operations will be the responsibility of Caltrans and the participating local agencies.

This work package provides support for system deployment and operations in the following areas:

F1. Pilot System Technical Deployment
F2. Pilot System Technical Training
F3. Pilot System Technical Support

PILOT SYSTEM TECHNICAL DEPLOYMENT

The pilot system components will need to be deployed into multiple locations in an organized and step-wise fashion. This task will accomplish this objective through:

1) Creation and management of a Deployment Manifest
2) Identification of a system architecture to develop, test, and produce system components
3) Identification of computer systems onto which the deployments will occur
4) Deployment of system components

PILOT SYSTEM DEPLOYMENT MANIFEST

In this task, the project team will maintain an updated manifest of all major components (hardware and software) of the system. The manifest will track the deployment status, deployment location, and current version of each major system component.

Deliverable:
1. ***Pilot System Component Manifest***

PILOT SYSTEM DEPLOYMENT PROCESS AND ARCHITECTURE

The project team will detail the steps involved in the deployment process. For instance, there will need to be a test system in which proper subsystem functionalities are verified before each functionality is migrated to the production environment.

Deliverable:
1. ***Pilot System Deployment Process and Architecture***

PILOT SYSTEM DEPLOYMENT

Deployment of the system will start once the manifest is agreed to, the deployment architecture is defined, and the required physical assets are available. While the initial deployment will likely involve a large number of components, the need to address software bugs and to tweak component characteristics will likely lead to the execution of many small deployment iterations within the overall system deployment process.

Deliverable:

1. ***Deployed ICM system components***
2. ***Deployment of system updates***

PILOT SYSTEM TECHNICAL TRAINING

TMC operators, managers, maintenance personnel, and interested stakeholders will require an introduction to the use of the system, as well as a contact person to go to when they have questions.

This will be accomplished through:

1) Pilot system training
2) Simple, easy to understand user guides

PILOT SYSTEM TRAINING

In this task, the project team and selected contractors will provide training to transportation operators that will be operating the newly developed systems. Training to support personnel, including IT staff for ongoing operations and maintenance of the system, will also be provided.

Deliverable:

1. ***Training materials***
2. ***Training sessions***

PILOT SYSTEM USER GUIDES

In this task, the project team will develop user guides for the system. These are envisioned to be accessible to TMC staff and managers.

Deliverable:

1. ***User Guides***

PILOT SYSTEM TECHNICAL SUPPORT

Help Desk Technology will be utilized to track usage issues, bugs, and enhancement requests. Technical support will also be provided to answer questions and fix system bugs.

Subtasks within this task include:

1) Provide a web site to report issues
2) Provide usage support
3) Provide bug fixing support

SUPPORT WEB SITE

The proper web based interfaces will be setup to record issues, bugs, and enhancements. Requests will be reviewed and responded to in a reasonable time.

Deliverable:

1. ***Web Site Functionality***
2. ***Timely review of issues recorded on the website***

USAGE SUPPORT

As users have questions, we must understand where the questions are coming from, appropriately answer them, and ensure that knowledge gained from the interaction is appropriately saved for use at later dates.

Deliverable:

1. ***Resolution of questions and issues***
2. ***Tracking of these resolutions***
3. ***Incorporation, as appropriate, into training and user guidelines***

BUG FIXING

Despite attempts to develop bug-free systems, all systems may have hard-to-detect bugs upon release. While a majority of bugs are typically found and resolved during testing, problems are sometimes uncovered after a system has been deployed. The project team will manages these bugs, and, as resources and priorities permit, address them.

Deliverable:

1. ***Bug Prioritization***
2. ***Bug fixing***
3. ***Bug fix testing***