Appendix D.2.6.a

Conceptual ITS and TCS Design for the IH 635 Managed Lanes Project: Final Document

JANUARY 2009
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<td>ITS</td>
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<td>President George Bush Turnpike</td>
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<td>POP</td>
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<td>Polyvinyl Chloride</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RWIS</td>
<td>Roadway Weather Information Station</td>
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<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SAN</td>
<td>Storage Area Network</td>
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<tr>
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<td>Supervisory Control and Data Acquisition</td>
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<td>System Integration Testing</td>
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<td>Description</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<td>Texas Department of Transportation</td>
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<tr>
<td>U.S. DOT</td>
<td>United States Department of Transportation</td>
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<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
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<tr>
<td>VAS</td>
<td>Video Audit Subsystem</td>
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<tr>
<td>VES</td>
<td>Video Exception Subsystem</td>
</tr>
<tr>
<td>VOA</td>
<td>Vehicle Occupancy Assessment</td>
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<td>Wide Area Network</td>
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EXECUTIVE SUMMARY

Cintra Concesiones de Infraestructuras de Transporte, S.A. and Meridiam have been invited by the Texas Department of Transportation (TxDOT) to submit a competitive proposal in enter into a Cooperative Development Agreement (CDA) to develop, design, construct, finance, operate and maintain the IH 635 Managed Lane (ML) project within an approximately 17 mile portion of IH 635 and IH 35E corridors in Dallas County, Texas. The construction of the managed lanes within this corridor presents multiple engineering, tolling and operational challenges. This report focus on the proposed technical and operational solution required for tolling, traffic management using intelligent transportation systems (ITS) technology and related communications along the corridor.

Design Overview

The proposed conceptual design and schematic for an Integrated Toll and Traffic Management System (ITTMS) meets the requirements of TxDOT and that is comprised of straightforward, sound and proven devices and methodologies. The transportation technology proposed for this project has been implemented on numerous projects in Texas, across the United States and overseas. The lane level toll collection system relies on technology that is operational in Texas. The components of our approach will meet the accuracy and performance requirements of the project.

The following are key components of the managed lane electronic Toll Collection System (TCS):

- **Toll Lane Systems**: At each of the tolling points, vehicles will self-declare as either High Occupant Vehicle (HOV) or Single Occupant Vehicle (SOV) by driving through a tolling lane designated for either HOVs or SOVs. Automatic Vehicle Identification (AVI) will be used to read the transponders of passing vehicles. The toll amount will then be automatically debited from the account associated with the transponder (except for exempt vehicles, which will be automatically identified). For vehicles without a valid transponder, license plate recognition cameras will capture images of the license plates for use in identifying and billing the registered owner. Automatic Vehicle Classification (AVC) will be used to determine the size or number of axles of the vehicle, as the toll amount due will depend on this factor. The toll may be discounted for HOV. Enforcement zones will provide locations adjacent to the roadway for enforcement officers to monitor HOV declaration and toll payment compliance. Dynamic toll rate signs located in advance of all tolling points will notify drivers of the toll rate in effect when they enter the managed lanes.

- **Toll Facility System**: The facility level central system will be in constant communication with the lanes. The facility system will process the video and transponder transactions sent up from the lanes and pass them to the North Texas Tollway Authority (NTTA) for posting to customer accounts. For video transactions, the images shall be manually reviewed for accuracy and legibility before sending to NTTA. The facility system will also house the pricing component responsible for setting the base toll rate in either dynamic mode or schedule mode. In dynamic mode, the base toll rate will adjust based upon the real-time traffic conditions. In schedule mode, the rate will adjust based upon the time of day. An interface to the vehicle detectors will provide the traffic conditions data needed to calculate the rate in dynamic mode.
The following are integrated into the ITTMS to provide traffic management capabilities:

- Closed circuit television cameras for 100% video surveillance coverage of project limits.
- Vehicle detection at half-mile spacing to collect traffic flow information that will be used to monitor traffic conditions and set toll rates.
- Dynamic message signs located along both general purpose and managed lanes in advance of major interchanges.
- Highway advisory radio will be located at each end of the project corridor to provide audio advisory information to motorists.
- Lane control signals positioned along depressed managed lanes with half-mile spacing, and approaches and access ramps to depressed managed lanes to assist motorists with highly visible lane control information.
- Over-height vehicle detection systems located in advance of access points to depressed managed lanes with height restrictions, along with blank-out signs to issues warnings to any vehicles surpassing these restrictions.
- Road weather information systems supported by pavement sensors to collect weather-related information that may be used to provide warnings to motorists.
- Traffic Management System (TMS) application software providing centralized control of all devices, centralized roadway monitoring capability, and incident reporting. Similar systems are operational in Texas and across the United States.

Approach to Toll Operations, Enforcement, and Interoperability

TOLL OPERATIONS

Because the North Texas Tollway Authority will be providing the back office and customer service functions for the project, the Consortium’s toll operation will be limited. The primary functions performed by Consortium staff will be the manual review of video transaction images prior to sending the transactions to NTTA, and the coordination with enforcement officers for on-site toll payment and HOV enforcement. Freeway operations and maintenance personnel will be required to monitor the roadway 24/7 to respond to incidents and quickly attend to any equipment malfunctions. The daily routines of updating, backups, trouble shooting, network maintenance, and system administration will require a group of systems professionals to keep the various systems operational. An operations program manager will provide general oversight and supervision.

ENFORCEMENT

Enforcement of the ML toll payment will be a two-pronged approach. First, license plate recognition cameras will be installed to capture images of each passing vehicle. If the vehicle does not have a valid transponder, the images will be retained, processed using Optical Character Recognition (OCR) to extract the license plate characters, manually reviewed by a Consortium-employed image review clerk (if it cannot be confidently “read” by the OCR), and sent to NTTA. NTTA will identify the registered owner of the vehicle via Department of Motor Vehicle records and mail a payment notice.
Secondly, manual on-site enforcement will be provided by officers stationed at enforcement zones located in proximity to the tolling points (when possible, per roadway design constraints). Signals would be installed at each tolling point for both HOV and SOV lanes, and triggered to turn on when no valid transponder is detected on a passing vehicle. This would provide a visual cue to a law enforcement officer that the passing vehicle did not pay a toll. The officers will be equipped with portable electronic devices that could access a secure website that displays license plates and images of potential violators as they pass the tolling point. This information could be used by the officer to make an enforcement stop. Once a potential violator is stopped, the driver may claim that they actually drove through the SOV declaration zone. Using a hand-held transponder reader, the law enforcement officer would be able to read the tag or enter in the license plate to make an inquiry concerning the veracity of the driver’s claim.

**INTEROPERABILITY**

The Comprehensive Development Agreement (CDA) and Technical Provisions require that the IH-635 ML project support Texas statewide interoperability in two key areas:

- **Tolling**: The Toll Collection System (TCS) system and any transponders issued by NTTA on behalf of the Consortium shall meet TxDOT statewide interoperability and compatibility standards, requirements and protocols, including participation in a statewide or regional toll payment clearinghouse. This includes interoperability with any other Texas tolling authority for which TxDOT has an interoperability agreement. ETC interoperability shall be demonstrated prior to tolling commencement.

  The Automatic Vehicle Identification system shall support the following tags:
  - **HCTRA**: TransCore models AT5544 (read only), AT5545 (read only), AT5547 (read only), and AT5140 (read/write)
  - **NTTA**: TransCore models AT5100 (read only), AT5145 (read/write)
  - **TxDOT**: TransCore model 13-0700-120 – eGo Plus™ Sticker

- **Intelligent Transportation Systems (ITS)**: The Consortium shall provide secondary access and control via a center-to-center interface to TxDOT for Dynamic Message Signs (DMS), Closed Circuit Television (CCTV) and vehicle detection systems. Data, video and status information from these devices shall also be provided to TxDOT. Additionally, interoperability shall be achieved with other TMCs in the region, including DalTrans.

**Maintenance and Renewal Work**

An integrated solution approach to the operations and maintenance of the systems shall be pursued, as the components of the ITTMS will share communications and control center facilities. The skill sets (communications, electronics, IT) required for operating and maintaining ITS and TCS are seen as similar across each type of system. Operations and maintenance staffing shall therefore be cross-trained and responsible for all aspects of each system, including: maintenance of central systems; field equipment; and communications.

The existing ITS field devices will keep operational throughout the construction process. As new system elements are accepted from the applicable contractors and system integrator, operations and maintenance staff shall be hired to the eventual planned size by the end of the construction process, with additional staff brought on as more sections of the systems are completed.
After construction is complete, the day-to-day maintenance program will include the following activities:

- **Routine Maintenance**: Maintenance activities performed at regularly scheduled intervals for the upkeep of equipment. This activity includes checking, testing and inspecting, recordkeeping, cleaning, and periodic replacement when called for in the preventive maintenance schedule. This proactive approach will minimize systems faults and breakdowns.

- **Responsive Maintenance**: The repair or replacement of failed equipment and its restoration to safe, normal operation. Typically unscheduled, it is in response to an unexpected failure or damage.

- **Emergency Maintenance**: Emergency maintenance is similar to responsive maintenance in that it is initiated by a fault or trouble report. However, in this case, the fault is more serious and requires immediate action. Events such as knockdowns, spills, exposed electrical wires, road blockages, etc. are examples of event reports that may require emergency maintenance. Of course, there can also be operational emergencies — e.g., stuck barriers on dedicated HOV lanes or failed lane control signs — that need to be dealt with quickly in order to minimize hazardous circumstances.

In addition to regular maintenance, the results of general system inspections will be used to plan for renewal work. The renewal effort will include the periodic replacement of field equipment, central hardware and software applications to address obsolesces, new technologies, and to increase efficiency.

**Work Plan**

The Work Plan in general will follow a systems engineering approach throughout the entire life cycle of the project, from initial mobilization and project kick-off, to final acceptance and project hand-off.

The Work Plan for the Toll Collection System (TCS) and the Intelligent Transportation Systems (ITS) involves the delivery of the toll, ITS and communication systems. A Systems Integrator approach is proposed, in which the Integrator is retained to be responsible for design, build and system integration of all transportation technology components. This approach would have the following key phases:

- **Design**: The system design will advance the conceptual design to the point where all aspects of the project are fully designed and ready for construction. The System Integrator will perform this effort. All equipment and cable installations will be designed and the functional requirements for all software will be finalized. It is expected that the detailed design for the highway sections will be completed in the same time frame.

- **Build**: The System Integrator will be responsible for all installation, integration and testing of the equipment, hardware, and software. The System Integrator will also be responsible for ensuring that toll collection and traffic management software is integrated with all of the field equipment. It is expected that the System Integrator’s software suite will largely be an existing application that will require configuration and minor modification to meet the needs of this system.

- **Testing**: A testing regime has been identified that provides sequential testing of equipment and software in order to help isolate problems and to make troubleshooting
easier. These include tests prior to installation, testing of each individual field device and subsystem, overall system testing, and finally, a 60-day live operations test.

- **Training:** Training for all users of the system shall be provided, including customer service representatives, etc. Maintenance and system administration training shall also be provided.

- **Documentation:** Full documentation of the system shall be provided, including detailed documentation of the system design, configuration, training, as-built conditions, operation and maintenance.
1. **INTRODUCTION**

Cintra Concesiones de Infraestructuras de Transporte, S.A. and Meridiam (together, the Consortium) are preparing a proposal for the development, design, construction, financing, operation and maintenance of the Interstate Highway (IH) 635 Managed Lanes (ML) Project in Dallas, Texas, through a comprehensive development agreement with the Texas Department of Transportation (TxDOT). Under Section 3.1 of the Comprehensive Development Agreement (CDA), the Consortium, if preparing the successful bid, will be authorized to collect tolls along segments of IH 635 and IH 35E in the Dallas, Texas area to finance the project. All toll collection will be through the use of a Toll Collection System (TCS) that includes Electronic Toll Collection (ETC) and License Plate Recognition (LPR) technology. There will be no toll booths or gates. The proposed lane level solution is similar to installation that are operational in Texas and elsewhere. The toll rates will fluctuate depending on the level of congestion in the lanes. Intelligent Transportation Systems (ITS) will be deployed to provide the real-time traffic volume data that is used to determine the dynamically-set toll rates. ITS will also be used to monitor and manage traffic conditions. The Consortium has retained IBI Group to serve as Technical Advisor for the integrated IH 635 TCS and ITS systems. This final design document provides our conceptual design and schematic drawings for these systems.

Design schematics showing proposed equipment locations are provided in Appendix A.

1.1 **Project Understanding**

The following describes our understanding of the project’s proposed highway improvements, based upon the documentation provided by the Consortium and TxDOT.

The IH 635 Managed Lanes Project consists primarily of the construction of a new Managed Lane Tolling System, with necessary tolling infrastructure. There will be some degree of reconstruction of existing mainline lanes to provide General Purpose lanes, as well as frontage roads and cross streets.

The project limits are along IH 635 from Luna Road (west of the IH 35E interchange) east to Greenville Avenue (east of US 75); along IH 35E from south of Northwest Parkway north to Valwood Parkway; and a short segment of Loop 12 from south of Northwest Parkway to IH 35E.

The ML will consist of three segments:

- **Segment 1** runs along IH 35E from the Loop 12 interchange to the IH 635 interchange. The ML will be accessible from both Loop 12 and IH 35E at the southern end of this segment. At the northern end of the segment, the ML will directly connect with the ML on IH 635 east of the IH 35E/IH 635 interchange. This will provide an opportunity for vehicles in the ML to make direct connections from northbound IH 35E to eastbound IH 635, and from westbound IH 635 to southbound IH 35E. The ML will be separate elevated structures for each direction through all of Segment 1.

- **Segment 2** runs along IH 635 from east of Luna Road to the Dallas North Tollway (DNT). The ML will begin on the western end of this segment as a transition from High Occupancy Vehicle (HOV) lanes inside the mainline lanes of the existing freeway, to separate ML. The ML will become separate elevated structures for both directions of
travel just west of the IH 35E interchange. The ML will remain elevated over the IH 35E interchange, and merge with the ML from the IH 35E ML just east of the IH 35E interchange. The ML will continue east, transitioning from separate elevated structures for each direction to submerged separate depressed lanes near Webb Chapel, and continue as separate directional depressed lanes through the DNT interchange.

- **Segment 3** runs along IH 635 from the DNT interchange to just west of US 75. The ML will be separate directional depressed sections at the DNT interchange, and continue to the east as separate depressed lanes up to near Hillcrest Road. Near Hillcrest Road, the depressed lanes will transition to rise and meet the General Purpose lanes near ground level. As the depressed section meets with the General Purpose lanes, the ML will merge inside the General Purpose lanes, transitioning into the existing HOV lanes in the center of the General Purpose lanes just west of the US 75 interchange.

The ML will have access points at the ends of each segment identified above, as well as through several on and off ramps from the General Purpose lanes and Frontage Roads. The details for these access ramps were not provided in the Comprehensive Development Agreement (CDA), but the attached schematic used to estimate system quantities reflects these access points as shown in Figure B-1 on Exhibit 4 – Toll Regulation of Book 1 of the CDA.

### 1.1.1 COMPLIANCE WITH TXDOT RFP REQUIREMENTS AND INDUSTRY STANDARDS

The conceptual design proposed by this document was developed to comply with the following documents, all references correspond to the latest document versions:

- Comprehensive Development Agreement (CDA) for IG 635 Managed Lanes Project,
- Programmatic CDA Book 2A
- Addendum 1 through 12 to the final Request for Proposals
- Programmatic CDA Book 2B
- Draft Tolling Services Agreement (TSA) with the North Texas Tollway Authority (NTTA)

The following documents were used as design references:

- Texas DOT Website for inventory of Closed Circuit Television (CCTV), Dynamic Message Signs (DMS), and vehicle detection
- Operational Concept Document for the DalTrans TMC
- Managed Lanes Handbook prepared by Federal Highway Administration (FHWA)/TxDOT
- Enforcement Issues on Managed Lanes prepared by FHWA/TxDOT
- Traffic Control Devices for Managed Lanes prepared by FHWA/TxDOT
- Staffing and Training Needs for Managed Lanes prepared by FHWA/TxDOT
- Center-to-Center Communications Concept of Operations 3.1.0 prepared by TxDOT
1.1.2 SERVICES PROVIDED BY NTTA

It is understood that the North Texas Toll Authority (NTTA) will provide customer service and back office services for the IH 635 ML project, including transaction posting, video toll notice generation, transponder distribution, and customer service functions. NTTA is the primary agency providing toll collection operations within the Dallas area. Toll roads managed by NTTA include the Dallas North Tollway (DNT), President George Bush Turnpike (PGBT), Addison Airport Toll Tunnel (AATT) and Mountain Creek Lake Bridge (MCLB).

The TCS must include an electronic data exchange interface with NTTA. The ML transponder transactions collected and processed by the TCS are to be electronically transmitted to NTTA for posting to customer accounts. Video Trip transactions will be electronically transmitted to NTTA for the generation of a request of payment to the owner of the vehicle. The Interface Control Document (ICD), found in Attachment 3 to the CDA Tolling Services Agreement, specifies the format that must be used for this interface. The Consortium's staff will review LPR images for legibility and accuracy before sending to NTTA. The Consortium is restricted from providing any of the customer service functions, including transponder distribution, provided by NTTA under the TSA.

1.1.3 STATEWIDE INTEROPERABILITY

The CDA and Technical Provisions require that the IH-635 ML project support Texas interoperability in two key areas:

1. **Tolling:** The TCS system and any transponders issued by NTTA on behalf of the Consortium must meet TxDOT statewide interoperability and compatibility standards, requirements and protocols, including participation in a statewide or regional toll payment clearinghouse. This includes interoperability with any other Texas tolling authority for which TxDOT has an interoperability agreement. TxDOT requires the Consortium to demonstrate ETC interoperability prior to tolling commencement. Details on interoperability requirements may be found in the CDA.

2. **ITS:** The Consortium is required to provide secondary access and control via a center-to-center interface to TxDOT for Dynamic Message Signs (DMS), Closed Circuit Television (CCTV) and vehicle detection systems. Data, video and status information from these devices shall also be provided to TxDOT. Additionally, interoperability shall be achieved with other TMCs in the region, including DalTrans.

This conceptual design addresses both of these requirements.

1.2 System Overview

The implementation of a managed lane program under the TxDOT requirements requires the close integration of the tolling and traffic management systems for three key reasons:

- **Dynamic Pricing:** The tolls for this project will be set in a manner to ensure that travel speeds on the managed lanes are kept at 50 mph. The data on traffic congestion required to determine current speeds would come from roadway sensors that are part
of the traffic management system and not the toll system. Comparable approaches are operational in Minnesota and soon to be implement in Washington State.

- **Event Tracking and Management**: The 50 mph performance requirement is not enforced when there are accidents, breakdowns and inclement weather that preclude the traffic moving at this speed. The Traffic Management System (TMS) provides the means to track and manage events.

- **Facility Management**: The Consortium will manage the roadway as a holistic enterprises and not a series of silos where each function is assigned to a different division. The integrated systems approach will provide managers with the tools to oversee every aspect of the facility.

The diagram on the following page illustrates the integrated concept that melds the individual system components into a consolidated whole. Each of these components is discussed in detail in the remainder of the report.
TEXAS IH 635 INTEGRATED TOLL AND TRAFFIC MANAGEMENT SYSTEM (ITTMS) OVERVIEW

Interface to NTTA

Toll Collection System
- Transponder Transaction Processing
- License Plate Transaction Processing
- Image Processing
- Image Review & Validation
- Dynamic Rate Setting
- System Monitoring
- Audit & Reconciliation

Integrated System Components
- Data Storage & Archival
- Reporting
- MOMS

Traffic Management System
- Traffic Data Collection
- Active Traffic Management
- Lane Control
- Event Management

ITS Field Equipment
- Dynamic Message Signs
- Cameras
- RWIS
- Detection
- Lane Control System
- Highway Advisory Radio
- Overheight Vehicle Detection

Legend

IH635 Integrated Toll and Traffic Management System Component
Third Party Component

Figure 1: System Overview
2. TOLL COLLECTION SYSTEM CONCEPTUAL DESIGN

2.1 Introduction

This section of the report presents the conceptual design for collecting tolls along the ML. The functions, features, and equipment required for a current state-of-the-art electronic toll collection system are detailed below. Key items to be addressed included:

- Toll System Principles which provide the underlying basis for design;
- System Architecture that describes how the physical components of the system connect and work together;
- Toll Collection Software Requirements that list the functionality of the application software;
- Toll Collection Equipment discusses the lane level hardware required for transponder and video toll collection, enforcement, security and traffic control;
- Equipment requirements for the tolling point field hardware and central systems;
- Need for Flexibility and Expansion Capabilities to accommodate changing standards and requirements.

2.2 Toll System Principles

The toll system principles help to define the design requirements for the toll collection system. Beyond the design criteria and guidelines found in the Technical Provisions, these principles provide additional guidance in determining the requirements and features of the toll collection system.

2.2.1 TOLLING LOCATIONS

The ML will have access points at the ends of each segment identified above, as well as through several on and off ramps from the general purpose lanes and frontage roads.

Proposed toll collection points are as follows: Table 1: Proposed Toll Collection Points

<table>
<thead>
<tr>
<th>Tolling Points</th>
<th>No. of Lanes</th>
<th>Mainlanes or Ramp</th>
<th>Reference Station Schematic from</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1a. NB IH 35E south of Loop12 merge</td>
<td>2</td>
<td>Ramp</td>
<td>1040+00</td>
</tr>
<tr>
<td>G1b. NB Loop12 south of IH35E merge</td>
<td>2</td>
<td>Ramp</td>
<td>1035+00</td>
</tr>
<tr>
<td>G2. NB IH 35E entrance ramp from Walnut Hill Road</td>
<td>2</td>
<td>Ramp</td>
<td>1102+00</td>
</tr>
<tr>
<td>G3. SB IH 35E-EB IH 635 - connector</td>
<td>3</td>
<td>Ramp</td>
<td>46+50</td>
</tr>
<tr>
<td>Tolling Points</td>
<td>No. of Lanes</td>
<td>Mainlanes or Ramp</td>
<td>Reference Station from Schematic</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>-------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>G4. EB IH 635-IH 35E entrance ramp</td>
<td>2</td>
<td>Ramp</td>
<td>50+50</td>
</tr>
<tr>
<td>G5. EB IH 635 entrance ramp just west of Marsh</td>
<td>2</td>
<td>Ramp</td>
<td>145+70</td>
</tr>
<tr>
<td>G6. EB IH 635 just east of Dallas North Tollway</td>
<td>3</td>
<td>Mainlanes</td>
<td>275+00</td>
</tr>
<tr>
<td>G7. EB IH 635 entrance ramp near Hillcrest</td>
<td>2</td>
<td>Ramp</td>
<td>353+70</td>
</tr>
<tr>
<td>G8. EB IH 635 entrance ramp near Floyd</td>
<td>1</td>
<td>Ramp</td>
<td>482+40</td>
</tr>
<tr>
<td>G9. WB IH 635 west of Greenville</td>
<td>2</td>
<td>Mainlanes</td>
<td>482+40</td>
</tr>
<tr>
<td>G10. WB IH 635 entrance ramp from Floyd</td>
<td>1</td>
<td>Ramp</td>
<td>456+00</td>
</tr>
<tr>
<td>G11. WB IH 635 entrance ramp from US 75</td>
<td>1</td>
<td>Ramp</td>
<td>394+50</td>
</tr>
<tr>
<td>G12. WB IH 635 entrance ramp west of Hillcrest</td>
<td>2</td>
<td>Ramp</td>
<td>340+50</td>
</tr>
<tr>
<td>G13. WB IH 635 just east of Dallas North Tollway</td>
<td>3</td>
<td>Mainlanes</td>
<td>275+00</td>
</tr>
<tr>
<td>G14. WB IH 635 entrance ramp just west of Midway</td>
<td>2</td>
<td>Ramp</td>
<td>186+60</td>
</tr>
<tr>
<td>G15. WB IH 635 exit ramp near Josey to IH 35E Connector</td>
<td>2</td>
<td>Ramp</td>
<td>10559+40</td>
</tr>
<tr>
<td>G16. SB IH 35E connector from WB IH 635</td>
<td>2</td>
<td>Mainlanes</td>
<td>1194+80</td>
</tr>
</tbody>
</table>

Upon approaching an entrance to the ML, vehicles will enter a Declaration Zone (DZ), requiring the driver to declare the vehicle as a Single-Occupant (SOV) or High-Occupant (HOV) for purposes of toll charging. Separate lanes will be dedicated for SOVs and HOVs. Enforcement officers stationed at enforcement zones (located at tolling points, within roadway design constraints) will provide HOV and toll payment enforcement.

Each tolling point will have declaration zones and enforcement zones as shown in the attached schematics.

### 2.2.2 VEHICLE CLASSIFICATION

The Consortium must indicate to TxDOT whether a factor based upon vehicle profiling or number of axles will be selected for the toll rate calculation. Exhibit 4 of the CDA allows the Consortium to choose a toll rate schedule that is based on one of these characteristics. As the vehicle increases in size or number of axles, the toll rate will be multiplied by the appropriate factor. Increasing the toll rate for larger vehicles is a common practice in the industry.

As a vehicle approaches the tolling point, its profile can be measured by infrared sensors, or the number of axles detected by in-pavement loops. This information will be included in the transaction data and used to calculate the toll amount due. Every tolling point shall have this capability.
2.2.3 METHODS OF PAYMENT

The TCS will use the Open Road Tolling (ORT) model of non-stop, all-electronic toll collection with License Plate Recognition (LPR) cameras to capture images of vehicles that do not have a valid transponder. Patrons without a transponder will be identified via their license plate number and a payment notice mailed to the registered owner of the vehicle. This approach is commonly referred to as “video billing”. Video billing services will be provided by NTTA.

2.2.4 PATRON PRIVACY

Toll transaction and patron identifying information collected by the TCS is considered Patron Confidential Information under the terms of the CDA. Therefore, the TCS must include both operational and system safeguards to protect this information. Section 2.4.7, System Security, provides requirements for such safeguards.

2.2.5 REDUNDANCY OF TOLL SYSTEM

The near perfect recording of the passage of every vehicle past a tolling point is a critical objective of a toll collection system. But once this event (either toll or video transaction) is captured, the information must reliably be transferred from the lane level through the plaza level to the host level for processing. The system design must have the ability to store information at the lane level until the transfer of the data is confirmed at the plaza level. A similar function must be implemented at the plaza level. Both the lane and plaza level must be able to store transaction information for at least 30 days in case communications to next level are disrupted.

2.2.6 ETC INTEROPERABILITY

The TCS system and any transponders issued by NTTA on behalf of the Consortium shall meet TxDOT statewide interoperability and compatibility standards, requirements and protocols, including participation in a statewide or regional toll payment clearinghouse. This includes interoperability with any other Texas tolling authority for which TxDOT has an interoperability agreement.

NTTA was an early adopter of the Amtech transponders. These original transponders were powered by the energy in the radio waves used to read the transponder. NTTA tags are marketed under the name of TollTag. The transponders used at the Harris County Toll Road Authority (HCTRA) are a later version of the Amtech transponders that are battery powered and marketed under the name of EZ TAG.

NTTA, as the customer service provider for the ML, will distribute eGo™ protocol “sticker” transponders under the TxTag name. New toll roads in Texas are required to provide readers that provide backward compatibility to both of the older Amtech transponders, as well as reading the TxTag.

The Automatic Vehicle Identification system shall support the following tags:

- **HCTRA**: TransCore models AT5544 (read only), AT5545 (read only), AT5547 (read only), and AT5140 (read/write)
- **NTTA**: TransCore models AT5100 (read only), AT5145 (read/write)
- **TxDOT**: TransCore model 13-0700-120 – eGo Plus™ Sticker
The existing toll authorities have established working protocols for the exchange of toll transaction information and transponder account information. Back-office compatibility with other toll agencies will be the responsibility of NTTA for this project. The Consortium shall be required to provide the compatible roadside equipment and interoperability shall be demonstrated prior to tolling commencement.

2.2.7 ENFORCEMENT APPROACH

Enforcement is a key element of any tolling operation, particularly for open-road facilities without toll booths or gates. While the primary enforcement mechanism for the Managed Lanes will be through the identification of violators via License Plate Recognition (LPR), on-site enforcement provided by law enforcement officers is also a necessity. On-site enforcement for the ML facility would include both enforcement of toll payment and enforcement of the High Occupancy Vehicle (HOV) lane restrictions. HOVs must meet the occupancy requirements for the road as well as pay a toll (at a reduced rate). To address these multiple requirements, the enforcement approach will be multi-pronged, consisting of a combination of available technologies, including:

- **Declaration Zone (DZ):** Upon approaching entrance to the ML facility, vehicles will enter a DZ where they must declare themselves as either an HOV or a SOV by moving into the appropriately designated lane. The vehicle is charged an HOV or SOV toll based upon its location in the chosen lane. This approach using declaration zones has successfully been implemented on California SR 91 in Orange County and I-25 in Denver.

- **Enforcement Signal:** Signals would be installed at each tolling point for both HOV and SOV lanes, and triggered to turn on when valid transponder is NOT detected on a passing vehicle. This would provide a visual cue to a law enforcement officer that the passing vehicle did not pay a toll.

- **Enforcement Zone:** Enforcement zones would be located on the shoulders next to the DZ tolling points (within the constraints of the roadway design). On-site enforcement officers would be stationed at the enforcement zones to visually verify that HOV-declared vehicles are traveling as such and also to provide ready pull-out access if the officer determines that a vehicle may be in violation based upon visual inspection of the vehicle occupants and/or the enforcement signal. The use of designated lanes provides law enforcement officials with clearer method of differentiating between a HOV and SOV than mixing both types of vehicles in a single lane.

- **Handheld Transponder Reader:** The enforcement officers would be provided with a handheld transponder reader that can interrogate the transponder of a pulled-over vehicle to determine if the transponder is valid; and if so, the date, time and amount of the last toll payment. This will assist the officer in determining whether a vehicle with a transponder that appeared to trigger the enforcement signal, is indeed a violator.

- **Roving Patrols:** A future option may be to provide enforcement officers with devices that automatically receive a real-time updated list of the transponders that have been read at the tolling point within a configurable amount of time. The officers shall then at random either drive alongside vehicles to confirm whether the vehicle has paid a toll. The technology would work whether the officer’s car is in motion or the target car is in motion or both are stationary. This is considered a future option because such a moving transponder reader is not currently available for eGo Plus™ sticker tags such as the TxTag distributed by TxDOT.
2.2.8 CUSTOMER SERVICE

The Consortium is required to contract with the North Texas Tollway Authority (NTTA) to provide customer service and back office processing for the project. This relationship will be governed by a Tolling Services Agreement between NTTA and the Consortium. NTTA is one of the two existing major toll authorities in Texas, and currently operates a customer service center in the Dallas area for walk-in service of new accounts and other transactions. NTTA also operates a customer service web site for 24-hour account access and opening of new accounts, a Customer Service phone number, and a “Tag Wagon” motor home that promotes TxTag at special events, such as fairs and festivals. NTTA provides the following services as part of their standard operations:

- Maintaining tag inventory.
- Testing, activating and distributing tags
- Opening, maintaining and closing customer accounts
- Processing customer transactions
- Collecting amounts due, including fees and video tolls, from customers
- Responding to customer inquiries and disputes
- Interoperability with other agencies in compliance with the TxTag statewide interoperability agreement, including processing of outside transactions and transferring of information and funds to other Texas toll operators.

Details on the precise services to be provided by NTTA, the specific obligations of the Consortium and NTTA, and the fees to be charged to the Consortium for NTTA’s services are set by the TSA.

2.2.9 DESIGN GUIDELINES, CRITERIA AND STANDARDS

Section 1.1.1 indicates the design guidelines, criteria and standards that have been adhered to and incorporated into the TCS conceptual design. The tolling system has been designed to meet the requirements of Section 21 of Book 2A and 2B with a focus on tolling performance requirements detailed in Section 21.5 of Book 2A. The design is in keeping with good toll industry practice and applicable Texas standards.

2.3 System Architecture

The following diagram summarizes the TCS architecture.
Figure 2: TCS Architecture Overview
2.4 Toll Collection Software Requirements

2.4.1 LANE SUBSYSTEM

The lane subsystem application is installed on the lane controller and provides the ability to collect tolls in the lane, capture images for video tolling, classify vehicles, inform and direct patrons and monitor lane level equipment. This open road tolling solution has been successfully implemented in Texas and other jurisdictions for hundreds of tolling lanes. The lane subsystem provides transfer, analysis, review, correlation/association, and filtering of data received from each component of the lane equipment.

2.4.1.1 Configuration

The facility TCS database will contain all configuration information for the toll system application. The applicable lane level information will be downloaded to the lane controllers. Configuration information will include the current toll rate schedules and transponder status lists. When the system is operating in dynamic mode, updated toll rates may be sent as frequently as every five minutes.

2.4.1.2 Equipment Status

Status information for all lane devices and appropriate diagnostic messages will be immediately updated to the facility TCS for immediate logging in MOMS and notification of appropriate parties.

2.4.1.3 Transaction Assembly

Conceptually, the lane subsystem includes two separate processes for transaction assembly: transponder transactions and video transactions. Video transactions are those for which no valid transponder is detected by the AVI system and instead, images of the vehicle’s license plate are captured and processed for later use in identifying the vehicle’s owner.

The design provides for an integrated lane controller for both types of transactions, with correlation of video images and classification information with specific transactions occurring at the lane level.

Transponder Transactions

Transponder transactions will be stored in the lane controller. Capacity to store up to 30 days of transactions in case communications are lost to the plaza server will be required. The transaction record should include the following information:

- Date and time;
- Transaction sequence;
- Lane identification (including whether the vehicle was declared as an SOV or HOV);
- Segment identification;
- Direction of travel;
- Transponder ID;
- Transponder status;
• Any violation or unusual occurrence;
• Vehicle classification;
• Segment toll amount due.

When a transaction is completed, the lane controller will store the transaction record. At regular intervals, the lane controller will upload new transactions to the facility TCS.

**Video Transactions**

If a valid transponder is not read when a vehicle passes a toll collection point, the lane controller captures information that supports further efforts to collect the toll. Video transaction data may include the following:

• Transaction ID;
• Vehicle images captured;
• Lane, segment and direction of travel information;
• Date and time;
• Status of in-lane equipment;
• Transponder number if read;
• Transponder status if read;
• Vehicle classification;
• Type of violation or unusual occurrence;
• Segment toll amount due;
• Codes referencing algorithms or rules used to process the transaction.

Images of all vehicles will be captured and correlation/filtering at the lane level will organize those transactions into video and transponder transactions. When a transaction is completed, the lane controller will store the transaction record. At regular intervals, the lane controller server will upload new transactions to the facility TCS for further processing.

### 2.4.2 FACILITY SUBSYSTEM

The Facility TCS is the central processing system for the IH 635 ML project. Processing of all transactions sent up from the lanes, calculation of the dynamic toll rate based on near-real-time traffic data, and financial audit/reconciliation are key functions of the facility TCS.

#### 2.4.2.1 Transaction Processing

At the facility level, the TCS will receive both the transponder transactions, for which a valid transponder read was associated with the vehicle, and the video transactions, for which video images of the vehicle’s license plate were captured in lieu of a valid transponder read. Raw data
from the lane will be sent to the facility TCS for assembly into complete trip transactions. The following processing elements are needed to assemble the transactions.

- **Interface to Tolling Points:** The Facility TCS shall monitor and control the electronic transfer of information from all lane controllers, including the status of all lane equipment and related communications links, individual transponder reads, and video images. The electronic transfer of information from all lane controllers should occur in near-real time. Additionally, the Facility TCS shall electronically transmit NTTA transponder status data files to all lane controllers at least once per calendar day.

  The interface shall include a mechanism for ensuring that data transfers have successfully transmitted the correct data. The lane equipment status data shall be processed to support maintenance monitoring functions and the operational display of current equipment status in near-real-time.

- **Video Processing:** The video processing function receives the video images captured at the tolling points and performs the Optical Character Recognition (OCR) review. The Facility TCS shall compare VES image data against lane transaction and transponder to plate association data:

  - For successful transponder read transactions (valid transponder and account), associated VES images shall be used to maintain a vehicle “fingerprint” with images and linked transponder/plate information stored in the Facility TCS. Image fingerprinting creates and stores a unique digital “signature” of the image. The “fingerprint” can then be used to automatically identify new images of the same vehicle and license plate if it is captured again in the future, even if those new images would not otherwise be readable. This approach provides another means to correlate transponders and vehicles to improve overall accuracy.

  - For successful transponder read transactions (invalid transponder and/or account), image data shall be forwarded for additional processing.

  - For unsuccessful transponder read transactions, VES images shall be compared with existing vehicle “fingerprint” and transponder/plate information to determine if the vehicle is linked to a transponder:

    - Image data linked to vehicle “fingerprint” and transponder/plate data shall be processed as Transponder Transactions.

    - Image data not linked to vehicle “fingerprint” and transponder/plate data shall be forwarded for manual image review and validation.

- **Image Review and Validation:** The OCR program is configured to flag images that cannot be deciphered within a certain confidence level. These images are then forwarded to a queue for manual review and validation. Image review and validation must be performed manually by Image Review Clerks employed by the Consortium. The manual image review rate for images below the confidence level is typically between 7-10%, with a higher review rate initially while the system is being calibrated. The Image Review Clerks will review these images to ensure that a legible license plate image was captured and that the correct plate number and jurisdiction are recorded. A configurable number of images shall be available for each transaction, with the clearest image “highlighted” by the OCR. The user shall be able to certify or reject an image by selecting an appropriate reject reason. An audit function shall be
provided for sampling and viewing records to verify correct OCR and manually entered license plate and vehicle information.

- **Calculation of Toll Amount Due:** The total toll rate due will be based upon the following data points: (1) the vehicle occupancy and classification as determined in the lane, (2) the number of segments traveled during the trip, and (3) the vehicle’s time of entry into the first segment regardless of whether the vehicle travels through one or several consecutive segments without exiting. The customer should not be charged any more than the amount displayed on the dynamic TRS at the time the vehicle entered the facility.

- **Special Considerations:** The system must be able to accurately identify and track Exempt Vehicles in order to comply with their exemption from tolls, and must be able to filter out transactions that occur during emergency toll suspensions as mandated by TxDOT.

It must be noted that elements of the transaction data and other data handled by the TCS are considered Patron Confidential Information under Section 8.8 of the CDA and must be protected. Transmissions from the roadside to the facility TCS, and from the TCS to NTTA should be encrypted. Safeguards to ensure the security of the stored data will be needed.

### 2.4.3 Dynamic Pricing

As noted, the system will use real-time traffic data collected by ITS vehicle detectors to determine the tolling rates based upon the level of congestion. The dynamic pricing function of the TCS would consist of the following three components:

1. **Interface to Vehicle Detection Data:** The ITS vehicle detection data should be provided in at least one minute increments, 24 hours per day, over the IH 635 project communications network. The vehicle detection data should include speed, volume, and lane occupancy, equipment status, latitude and longitude, route number, direction, and cross street for all lanes on all segments of the facility. An interface monitoring function would monitor equipment failures and ensure that the data transfer has successfully transmitted the correct data. The format of the data would be determined during the design of the system and documented in an Interface Control Document (ICD).

2. **Dynamic Rate Calculation:** The system shall include a dynamic, real-time, parameter-driven pricing algorithm calculation that provides the ability to calculate a toll rate based upon the current level of congestion in the Managed Lanes. The dynamic rate calculation shall adjust the base toll rate as often as needed, but not more often than every five minutes, in order to manage demand on the ML and meet the performance requirements of the facility. Calculations may be performed based upon the performance of individual segments or for the facility as a whole, but shall be calculated for each direction independently. A manual override function shall be used to suspend toll collection for a given segment or the entire facility. A historical toll rate database will store all displayed daily toll rates calculated by the real-time dynamic pricing algorithm for future analysis.

3. **Dynamic Rate Display:** The dynamic rate display function will control the dynamic TRS signs by sending commands to display the calculated current toll rates for each segment. The system shall have the ability to post the toll rate or other appropriate message (e.g., Closed, Open to All Traffic, HOV Only) on the dynamic TRS in real time.
The TCS facility software shall be capable of calculating trip tolls in either schedule mode or dynamic mode. Schedule mode shall set the base toll rate dependent upon the time-of-day for peak and off-peak travel. For the first 180 days following Service Commencement, the ML shall operate in schedule mode and tolls shall be collected based upon these pre-approved time-of-day base toll rates. The initial schedule mode table of toll rates shall be submitted by the Consortium in the format required by TxDOT at least 90 days prior to the Service Commencement Date. After the initial period, the TCS shall operate in dynamic mode.

The toll payment due for each segment shall be calculated with the following formula:

\[ \text{Segment Toll Due} = (\text{Base Toll Rate} \times \text{Segment Length}) \times \text{Maximum Toll Factor} \]

The base toll rate shall be set by the Consortium for each segment and direction to encourage and stimulate demand while maintaining an average speed of 50 mph. The base toll rate is currently capped by TxDOT at a maximum of $0.75 for the first 180 days following service commencement, unless conditions given under section 6 (c) of Exhibit 4 to the CDA are met.

The segment length is the length of the segment in miles.

The maximum toll factor is a whole number multiplier set by TxDOT and based upon either the occupancy and size of the vehicle or the number of vehicle axles. The total trip toll shall be the sum of all segment tolls for the single trip.

When in dynamic mode, the TCS shall continuously receive near-real-time traffic data from the ITS traffic detectors installed along the length of the facility. The TCS shall then calculate the HOV and general purpose ML base toll rates for each segment in each direction depending upon the level of congestion. Level of congestion shall be determined by parameters such as traffic volume and traffic flow (vehicles per hour). The base toll rate shall adjust as needed to manage congestion, but not more often than once every 5 minutes while in dynamic mode.

As required by TxDOT, the Consortium shall maintain indicative averages of the base toll rates for the previous 180 day period while the system was operating in dynamic mode. This information shall be made available to interested parties via Internet, fax, or hard-copy request.

2.4.4 INTERFACE TO NTTA

Before the TCS transmits a transaction to NTTA for processing, the system must compare the captured transponder numbers and license plate numbers to the current Consolidated Master List received from NTTA. Transactions that can be associated with a valid transponder will then be transmitted to NTTA as “transponder transactions”. Otherwise, transactions will be sent as “video transactions”. A check of the Vehicle Classification against the Vehicle Classification of the associated transponder must also be made prior to sending to NTTA.

Upon receipt of the transactions, NTTA will also perform a check of the tag and license plate data with its own records and that of other partnering toll facilities. If a match is found for a customer in good standing, NTTA will debit the account and remit the collected toll to the Consortium, minus any applicable fees. If no match is found, the registered owner of the vehicle will be identified based upon Department of Motor Vehicle records, and a video toll payment notice sent. Funds recovered from the video toll notice, minus applicable fees, will be remitted to the Consortium.

All transmissions to NTTA must be in the format specified by the ICD provided with the TSA.
2.4.5 AUDIT AND RECONCILIATION

Toll system reconciliation and audits are an important aspect of revenue management. The toll system shall provide analysis and reporting to allow reconciliation and audit of the various operations as described in this section.

In general, financial reports shall provide summary level data sorted by number of occurrences for initial review, and detailed transaction data filtered by the individual responsible for subsequent investigations. Individual performance (of a customer, specific personnel, or an external merchant service provider) shall be compared with overall performance (for all similar customers, personnel, or service providers) for the action being considered.

As the Facility TMS shall interface with NTTA to transfer Transponder and Video Transactions and to receive transaction dispositions and video toll status information, the TMS shall record Transaction Disposition data, including payments and debits due to overcharges/refunds, to the Consortium's financial institution account.

The Facility TMS shall interface with the Consortium's financial institution to receive bank deposit information, and shall store Transponder and Video Transactions, transaction dispositions, video toll status information, and bank deposit details. These records shall be stored and auditable accordance with Good Industry Practice and TxDOT requirements.

The system shall allow users to access and review these transactions stored in the central database based on a variety of search filters (e.g., date, location, status, etc.).

The Facility TMS shall maintain a record of at least the following transaction types:

- Transponder Transactions sent to NTTA
- Video Transactions sent to NTTA
- Transponder and Video Transactions failing transfer to NTTA
- Transponder Transactions, with transponder vehicle category that conflict with the AVC category
- Invalid Transponder Transactions
- Revenue deposited in the Consortium’s financial institution
- Expected revenue based on the Managed Lanes traffic count
- Non-Revenue transactions
- Discount Transactions
- Adjustment Transactions

The Facility TMS shall provide a user interface that enables, as a minimum, the following audit/reconciliation functions:

- **Adjustments**: Create and reverse.
- **Bank Deposits**: Create, adjust, and reconcile.
• **Exceptions**: System alerts of a configurable set of transaction types requiring data analysis/audit.

### 2.4.6 VIDEO AUDIT SUBSYSTEM

This subsystem will provide a means for toll auditors or supervisors to visually verify transaction occurrences in the lane in comparison to actual financial records and data recorded by the lane hardware.

The subsystem will synchronously link images from digital surveillance cameras in each lane to transaction data recorded by the lane subsystem, combining data and video at the same point in time. The linked data will include time/date/location stamps, financial data, and operational data; such as axle counts, vehicle classification, and toll expected/toll paid.

The subsystem will allow the video audit data to be searchable by transaction number.

The subsystem will provide real-time, online access to the digital video images.

### 2.4.7 SYSTEM SECURITY

Personnel passwords will be incorporated to prevent unauthorized access to the system. The system administrator will selectively grant access to each system function to each user ID.

The system will have the ability to require passwords to be changed periodically.

Access to certain critical system functions may require more than one password and user ID.

Data backup capability will be provided to the extent that no more than one business day of information is lost in the event of a system malfunction, disaster, or malicious interference with the system. System disaster recovery operations will allow for the complete restoration of the existing system, or the re-installation of a replacement system.

All transmission of customer information, particularly financial information, will be over a secure, encrypted connection. All staff access to stored customer data will be on a “need to know” basis only, with access to be set by the system administrator.

### 2.5 Toll Collection Lane Configuration

This section describes the configuration of the tolling points and toll equipment in the managed lanes.

#### 2.5.1 TOLL COLLECTION POINTS

The toll collection points for the ML will be either two or three lanes depending on location, as shown in Section 2.2.1 and in the diagrams on the following pages. Tolls will be collected at two types of tolling points: segment transfer points and declaration zones. Declaration zones are located at the access points to the facility and require the driver to self-declare as either a High Occupancy or Single Occupancy vehicle for purposes of assessing the correct toll. As the total trip toll is the sum of the segment tolls traveled, segment transfer points are located between segments 1 and 2 and segments 2 and 3 to toll vehicles already traveling on the ML when their trip crosses into another segment. The toll collection points are shown in Appendix A.
2.5.2 TOLL COLLECTION LANE EQUIPMENT

Each tolling point along the managed lanes will be equipped with the necessary devices and subsystems required to identify vehicles using transponders and video, classify the vehicle, provide information on vehicle occupancy, support enforcement activities, and enable the audit of individual transactions. The primary toll lane equipment has been deployed in Texas and at hundreds of ORT lanes around the United States and world.
Figure 3: Three Lane Tolling Point
Figure 4: Two Lane Tolling Point
The requirements and functions of each component are discussed below.

2.5.2.1 Dynamic Toll Rate Signs

Dynamic Toll Rate Signs (TRS) shall be provided in advance of all tolling points to notify drivers of the current toll rates. This type of signage has been deployed successfully in Minnesota as part of their managed lane program. All signs must be placed far enough upstream of the tolling points so that the user may make an informed decision of whether or not to enter the managed lanes. Although the rate may adjust while the vehicle is still en-route, the amount charged to the toll account shall remain the same as was posted to the TRS at the time of entry. The system shall keep track of the times that updated rates are published to the TRS.

The recommended approach is to install a sign showing the price for the single segment being entered, but to consider provisions for additional signage that would show the prices for all segments if desired later on, per the CDA Exhibit 4.

The TRS shall be NTCIP-compliant, one-line, eight-character (each character is approximately 18 inches tall by 8 inches wide), amber LED (9 by 4 pixel matrix for each character) signs. Each dynamic rate sign shall be mounted overhead within a static sign board displaying information related to the ML. The TRS shall be Internet Protocol (IP) addressable, and the DMS controller will be controlled by the using the National Transportation Communications for ITS Protocol (NTCIP).

The facility TCS shall change the TRS to the appropriate message as determined by the dynamic pricing algorithm in real time including toll rates and other messages, such as CLOSED or OPEN TO ALL TRAFFIC.

The dynamic portion will be an amber Light Emitting Diode (LED) panel that displays the dynamically changing toll rate or other message and is permanently attached to the static sign.

The TRS shall be managed by a sign controller located at the roadside or on the sign support structure in a weatherproof (NEMA 4x) enclosure.

The DMS will include an automatic feature that measures the ambient light and adjusts the intensity of the LEDs to be visible under all light conditions (full sun to full dark).

The facility TCS shall interrogate the TRS to verify what toll rate and/or message is being displayed by the TRS and shall record this verification for processing and reporting purposes.

The facility TCS shall have the ability to interrogate the TRS to determine the status of the TRS field equipment and record the status for processing and reporting purposes.

The systems integrator shall integrate the TRS into the electronic toll collection system for the display of the current toll rate.

If communication to the TRS is lost, the TRS shall be programmed to display a default message.

2.5.2.2 Detection and Automatic Vehicle Classification (AVC)

The system will support both smart loops and laser profilers to detect vehicles entering/exiting the tolling points, to determine separation between vehicles, and to determine the number of axles or size for each vehicle depending upon the pricing scheme chosen by the Consortium.

The AVC shall classify each vehicle passing through the tolling zone in accordance with CDA Exhibit 4.
The AVC shall detect whether a vehicle is present, determine the User Classification, and have the ability to accurately distinguish individual vehicles.

The AVC equipment shall detect and count vehicles passing through the tolling points.

The AVC equipment shall electronically transmit the detection of each vehicle and associated classification information from the tolling point to the lane controller in real time.

The AVC equipment shall provide a trigger for the Video Exception Subsystem (VES).

The AVC equipment shall be accurate in all weather conditions and lighting conditions common to the Dallas, Texas area.

The facility TCS shall have the ability to interrogate the lane controller to determine the status of the connected AVC equipment and record the status for processing and reporting purposes.

The facility TCS shall provide an automatic alert to MOMS in the event of AVC equipment failure.

2.5.2.3  Electronic Toll Collection Equipment

The ETC system devices will allow two-way dedicated short-range communication (DSRC) between the roadside infrastructure (reader and antenna) and transponder equipped vehicles using the ETC toll lanes.

The total series of transactions between the reader and transponder required for the successful interrogation of the transponder will be repeated at least twice to provide redundancy.

The DSRC subsystem will provide system security to protect against counterfeiting (anti-fraud transponder authentication) and intrusion.

The equipment required to provide ETC is specified below.

Reader

- The ETC reader will communicate with the transponder at a bit rate of 500 kb/sec for downlink of data and at bit rate of 250 kb/sec for uplink of data.

- All transactions between the reader and transponders, independent of the number of antennas connected to the reader, will be reported through a single communications channel.

- The reader will successfully identify vehicles traveling from 0 up to 100 mph through the toll lane with correctly mounted transponder, more than 99.90% of the time.

- The reader will process the data message received and transmit the information to the lane controller.

- The reader will accommodate all transponders supported by the TxTAG program.

Antenna

- Each toll lane of typical lane width (approximately 12 feet) will be sufficiently monitored by a single antenna so that no correctly mounted transponder equipped vehicles (including motorcycles) can avoid being detected while passing through the ETC lanes.
• Each antenna will be mounted the underside of a canopy or on a gantry structure.

• The ETC reader will facilitate accurate and simultaneous communications with transponders in vehicles traveling in a single lane.

• The system will not allow cross lane reads of transponders from adjacent toll lanes.

2.5.2.4 Video Exception System

The purpose of the Video Exception System (VES) is to deal with toll violators by automatically detecting vehicles without a valid transponder and collecting violation evidence (including vehicle images with vehicle license plate) to be used in the generation of a video toll payment notice.

Provision will be made to associate toll transaction information with each video toll image.

During the detailed design phase, the method for correlating this information should be determined (e.g., use of the AVC system or vehicle separator or an independent inductive loop to trigger the VES camera).

The main components of the VES include two digital cameras, a frame grabber, an illumination device, a VES controller, and storage device.

The system will provide a series of images of the front and rear license plates.

The VES will be parameter/table driven and allow the user to modify the parameters/tables without requiring substantial software changes.

The VES images will be suitable for manually identifying the complete vehicle license plate from 98% of all toll transactions where the license plate is unobstructed.

The equipment required for a VES is specified below.

Digital Camera

• The VES will use grayscale and/or color progressive scan digital cameras.

• The camera technology and its installed position will provide an image of the license plate that has a minimum of 12 pixels per inch of license plate. For US license plates this translates to a minimum of 200 pixels of horizontal license plate on the image.

• Resolution of the image will be high enough for manual license plate recognition through a standard computer monitor and through hardcopy printout. Also, image quality will be suitable for optical character recognition.

Illumination

Illumination will be provided to ensure:

• At all times of the day the vehicle’s color and license plate number on the reflectorized type of vehicle license plate is captured in the image taken.

• The license plate number of the vehicle shall be legible in all poor lighting conditions with the exception of exceptionally adverse weather conditions.
VES Controller and Storage Unit

- The VES controller will control the camera operations and data transmission between the local storage unit and the communications with the central software.

- One VES controller will control operations of all video toll enforcement cameras provided in a toll lane (up to a maximum of four (4) cameras).

- Video toll data will be recorded and security encrypted simultaneously on-site in digital form.

- Security measures will be provided to ensure that the keys, codes, and/or formulae for decryption will only be made available to relevant parties.

- Programmed and recorded information in the controller and the storage unit will be retained for a minimum of thirty (30) days after power failure.

2.5.2.5 Enforcement Signal

Signals would be installed at each tolling point for both HOV and SOV lanes, and triggered to turn on when no valid transponder is detected on a passing vehicle. This would provide a visual cue to a law enforcement officer that the passing vehicle did not pay a toll.

The systems integrator shall furnish and install electrical leads from the enforcement signal to the communications cabinet. The Integrator shall be responsible for terminating the enforcement signal to the integrator-supplied equipment that will energize and control the enforcement signal.

The 120V signal shall have sufficient power to be visible in all conditions while not so bright as to cause a distraction or hazardous conditions when flashing.

2.5.2.6 (Future) Vehicle Occupancy Assessment

Traditionally, it has been the responsibility of the driver to correctly declare the occupancy status of his vehicle when passing through a tolling point. This method requires a law enforcement officer to ensure compliance with vehicle occupancy the rules. Emerging VOA technologies may provide a promising approach that uses devices to measure various frequencies of infrared light which are indicative of human skin. The system can also distinguish facial structures between humans and other species for the purpose of differentiating between a second passenger and a pet. The VOA hardware could be use to identify vehicles of interest to improve the efficiency of the law enforcement effort. Upon a more detailed performance review of this equipment, it may prove to be within the best interests of the Consortium to include this automatic VOA system into the managed lanes if an available system can be demonstrated to meet the performance requirements given in Exhibit 4 of the CDA.

2.5.2.7 Lane Controller and Cabinet Assembly with UPS

A computer designed for relatively harsh conditions is used to manage the operation of each lane. The lane controller interfaces with the various lane devices with protocols unique to each device. The controller and interfaces are housed within a NEMA type cabinet.

- The lane controller will be an industrial grade PC used to control all toll collection functions and to transmit information and data on all the lane activities to the plaza server and then onto the primary server located in the administration building.
- The lane controller will monitor and control all peripheral toll collection devices connected to it.

- In the event of a central communication network failure, the lane controller will operate in a standalone local mode and toll collection will not be affected.

- The lane controller will have the capacity to store thirty (30) days of transaction data and ten (10) days of archived transaction data.

- Transaction data storage requirements will be estimated based on traffic volumes.

- The lane controller will allow data to be transferred using removable media.

- The lane controller chassis will be rugged and industrial grade.

- All lane controllers will interface to the plaza server via a Local Area Network (LAN) using standard communications protocols such as Ethernet. Physical cabling connections will be of the CAT5 Ethernet.

A cabinet will be supplied that is equipped to maintain a constant temperature at the nominal temperature of the toll equipment within the sealed equipment area of the cabinet.

- For outdoor placement of lane controllers, the cooling assembly will be adequate to keep the temperature in the equipment area of the cabinet between -5°C and +30°C with 2000 watts of dissipated heat from the equipment plus any heat expected from the cabinet utility equipment.

- The latching handles will have provision for padlocking in the closed position and will be constructed of cast aluminum or steel. The handle assembly will be zinc plated and coated with the same paint color as the cabinet paint finish. The door hinge pins will be stainless steel. The hinges will be bolted to the cabinet using stainless steel hardware.

- A trouble lamp with a basket protection will be mounted near the top of the door. The trouble lamp will be capable of being removed from its holder for inspection purposes, without the use of tools. The trouble lamp will be capable of reaching anywhere in the cabinet.

- The cabinet will be equipped with a grounding bar for connection to the terminal block.

- A lane UPS will be provided for each toll collection lane providing power supply in the case of a power outage. Selection of the lane UPS system requires a detailed design of the toll lane system with accurate power estimates.

### 2.5.2.8 Video Audit

Each tolling point will have equipment that collects live, streaming video of the vehicles that pass through the tolling point. The video stream is indexed against the transactions at the facility level. At the lanes, at least one CCTV camera per lane would be installed for surveillance purposes. The video feed would be sent to a digital recorder box in the equipment cabinet.

### 2.5.2.9 Power Requirements

Power requirements for each field location are provided in Appendix B.
2.6 Flexibility and Expansion Capabilities

Over the fifty years of the project, the technology for toll collection will change and volumes will increase. This section describes how these issues will be addressed.

2.6.1 CHANGES IN TECHNOLOGY

Over the fifty years of the project, the technology for toll collection will change. The US Federal Communication Commission (FCC) has designated the 5.9 GHz radio frequency band to be used for wireless communications applications that enhance transportation and public safety, including, AVI and ETC applications. The US Department of Transportation (US DOT) intends to use the 5.9 GHz band as a basis for a national dedicated short-range communication (DSRC) protocol to enable interoperability among devices and applications. US DOT is currently funding an effort to develop a first-generation prototype 5.9 GHz tag. Prototypes should be tested next year. The final deployment decision should occur with the next several years, followed by a transition period. This will be a national decision and would generate a mandate from TxDOT to the Consortium. As a member of Team Texas, that oversees the interoperability agreement, the Consortium will have an opportunity to provide input on new requirements before they are implemented. The new DSRC standard offers the promise of a built-in tag in every new vehicle, which would significantly reduce the amount of image processing and associated cost. In line with fulfilling the Consortium’s obligations under the Texas interoperability agreement, the Consortium will stay up-to-date with the progress of the nationwide standardization effort.

It is anticipated that new models for toll collection would emerge over the duration of the CDA. As these models are defined, the Consortium will make prudent business decisions on the effectiveness, efficiency and cost of migrating to another paradigm. Overall, the cost to collect tolls per trip should decrease in the future, as tags become standard equipment on all vehicles, and the number of video transactions will decrease accordingly.

The overall renewal strategy for the project calls for the periodic renewal and replacement of field equipment and central system software applications. These programmed activities will provide the occasion and opportunity to incorporate these potential changes in toll technology and update the components of the system.

2.6.2 EXPANSION

The initial toll collection system will be design for the transaction volumes anticipated during the first 20 years of the concession. The renewal strategy calls for upgrading central system hardware every five years. This will provide periodic opportunities to increase storage and processing capacity as volumes increase. As noted above, the use of transponders should increase over the life of the concession. The reduction in video transaction will decrease and actually reduce image storage requirements.

The system will have the ability to add additional tolling points or toll rate signs, if operational considerations warrant the need. The system will be configurable to accommodate these types of additions.

3. ITS CONCEPTUAL DESIGN

This section of the report presents the conceptual design for the Intelligent Transportation System (ITS). The ITS portion of this project includes field equipment which is connected over the
communications infrastructure to the Traffic Management System (TMS) application software and central computer hardware. The functions, features, and equipment required for a current state-of-the-art system are detailed below. Key items to be addressed included:

- High level principles which provide the underlying basis for design;
- System Architecture that describes how the physical components of the system connect and work together;
- ITS Software Requirements that list the functionality of the TMS software; and
- Field Equipment functional and installation requirements.

3.1 ITS Principles

There are four primary components to any ITS or TMS deployment.

- **Traffic Monitoring:** Traffic monitoring gives the users the opportunity to 'see' what is happening on their network. This may include visuals through CCTV or data through weather or traffic detection sites. For the managed lane project, this ability to monitor traffic in real time is at the heart of dynamic pricing.

- **Control and Response:** This is the core of the system and is where the system data analysis, system logic and device interface occurs. It provides an interface between the system and the users that is intuitive and easy to use and allows the user to control the devices in the field and record operational data. Control will extend to the use of the dynamic pricing algorithm to manage demand and to use the lane control signals to better direct traffic.

- **Information Dissemination:** Information dissemination gets the key information out to the motorists so that they can make informed route decisions based on real-time information and travel time. This includes event information and travel time.

- **Center-To-Center Interfaces:** Data sharing between centers is as crucial as geographic interfaces between operating agencies is transparent to motorists. Agencies must be aware of what is happening on parallel and interconnecting roads so that more information can be passed on to motorists and operators can make more informed decisions. Links to DalTrans will be incorporated into the design of the system to address this design principle.

3.2 ITS Standards

As the ITS industry advances, there has been a significant effort on the part of the US Department of Transportation to adopt national standards and related requirements. These efforts involve to primary areas:

- **National and Regional ITS Architectures:** The defining resource for providing guidance to state and local jurisdictions with regards to ITS projects is the National ITS Architecture. This resource was developed for the U.S. Department of Transportation (US DOT) to serve as a common framework for planning, defining, and integrating intelligent transportation systems. Final Regulations issued by the U.S. Department of Transportation require the development of a Regional ITS Architecture to serve as a
regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects. All projects that use federal highway trust funds are subject to this requirement. Thus, the Regional ITS Architecture and individual ITS projects must conform to the National ITS Architecture. This project will work with the North Texas Council of Governments to ensure that this project is in conformance with the local Regional ITS Architecture.

- **National ITS Standards:** The U.S. DOT ITS Standards Program is working toward the widespread use of standards to encourage the interoperability of ITS systems. The ITS Standards govern communications between the following interfaces between various ITS subsystems as defined in the National ITS Architecture:
  - Center to Center (Example: Traffic management Center (TMC) to Emergency Dispatch Center)
  - Center to Roadside (Field) (Example: TMC to DMS)
  - Center to Vehicle/Traveler (Example – Information service provider to kiosk, Emergency Dispatch Center to emergency response vehicle)
  - Roadside to Roadside (Example – traffic signal controller to railroad crossing equipment)
  - Roadside to Vehicle (Example – transit signal priority or electronic toll collection)

This project will incorporate the use of applicable and adopted ITS standards into the final design of the system and in concert with locally adopted interface standards.

### 3.3 System Architecture

The following illustrates the ITS Architecture.
Figure 5: TMS Architecture Overview
3.4 Application Software

3.4.1 ADVANCED TRAFFIC MANAGEMENT SOFTWARE

The Traffic Management System (TMS) operation and function is based on a centrally managed system in which operators, located in the control room (housed in the CCS), are able to use systems (including computers and communications devices) with the appropriate human/user interfaces to perform the following basic functions:

- Traffic monitoring and incident detection;
- System device monitoring and control;
- Incident response; and
- Information dissemination.

An integrated environment will be provided such that all of the traffic management, system control, CCTV and network management system controls are located at each operator workstation. TMS applications are widely deployed in Texas and across the United States and the world. The TMS in used by DalTrans is an illustrative example of how these system can be deployed to effectively manage traffic.

Each workstation shall use the operator interface software, the functionality of which is described below.

The operator interface will be based on a color graphical user interface (GUI), which will include the following general features:

- Windows environment;
- Audio-visual alarms;
- Pop-up and/or pull-down selection menus and help information;
- Item selection by point/click and drag/drop;
- Data entry forms which utilize scrollable selection lists, context saving and techniques to minimize data entry requirements;
- Schematic and scaled map based displays.

The operator interface will provide the following features:

- Map display;
- Operator dialogue;
- Windows for system monitoring and control;
• Menus and toolbars to access system facilities; and
• CCTV control.

3.4.2 TRAFFIC MONITORING AND DETECTION

This section describes the TMS means of traffic monitoring and event detection.

Given the urban nature of IH 635 and the inclusion of a significant depressed section, the design approach is to provide substantial network of roadway sensors to provided monitoring capabilities and automated incident detection. The roadway sensors will also provide a source of speed and travel time information that will be needed to monitor the average speed performance requirements found in Section G of the Exhibit 4 – Toll Regulation in the CDA.

The system will deal with unplanned and planned events. An unplanned event may include incidents, breakdowns, traffic congestion, AMBER Alerts, emergency maintenance, or inclement weather. A planned event is one where prior knowledge of the event is known, for example road works or construction, maintenance or special events.

The software shall allow the operator to open a new event, fill in pertinent information such as event type, cause, location, lane blockage patterns and other information that is relevant to each event type. Event start, end, duration, and updates will be stored in a central database. This blockage information is critical given the performance requirements in Section G of Exhibit 4 – Toll Regulation. The Consortium is held to an average speed requirement of 50 mph unless there is evidence of an event that reduces the capacity and speed of the roadway. The software shall provide the means to track and document these occurrences.

Traffic monitoring, including travel time and traffic data collection will be completed automatically by the system without the need for operator involvement.

3.4.2.1 Unplanned Events

Operators will use the CCTV to monitor the traffic to detect incidents that occur. With the high market penetration of cell phones, the majority of incidents are declared by motorists through 911. Therefore, the operators will also receive unplanned event information from 911 dispatch or the Police.

In addition, the traffic sensor data will be used to as input to incident detection algorithms. When an incident is detected, the operator will be alerted. The system will also alert the operator if speeds in the managed lane fall below the 50 mph threshold.

Pavement sensors and roadway weather information system (RWIS) will provide another source of information on travel conditions and provide alerts to the operators.

Over-height vehicle detection warnings will be automated but reported to the operator and stored in the database. The operator will be alerted to monitor those sections of the managed lanes.

Communication with the maintenance crews will provide details on emergency maintenance requirements that may impact the road. Motorist Assistance Patrols, if provided, will also pass event information to the operator.
3.4.2.2 Planned Events

Planned events will be entered into the system by the operator prior to the start of the event. Planned events would include construction and maintenance closures. There may be multiple sources for the information, including maintenance crews and other interagency coordination groups.

3.4.2.3 Travel Time

Travel time will be generated by taking the speed from the microwave vehicle detection (MVD) sensor and dividing it by the distance that the MVD effectively covers (generally ½ the distance to the upstream and downstream MVD). The travel time will be compared against the free flow travel time and if there are substantial variations, the information will be flagged. The operator can then try to determine if there is a reason for the discrepancy such as an incident or congestion.

Travel time data may also be crosschecked against the probe data gathered through the toll system.

3.4.2.4 Traffic Data

Traffic monitoring traffic data collection including speed, volume, and travel time will be completed automatically by the system without the need for operator involvement. This data will be the primary source of information required to set the tolling rate when the Managed Lanes are operated in the Dynamic Mode. The data shall be available in 20 second increments for use in the dynamic pricing algorithm as developed for this project.

3.4.3 SYSTEM DEVICE MONITORING AND CONTROL

The TMS will support real-time monitoring and control of system devices. Device monitoring will include the detection of failure states through messages sent to central by field control equipment. Device control actions include:

- Downloading initial and reset configurations;
- Synchronizing device clock; and
- Initiating requests for maintenance crews' attention

The system design will combine alerts from all hardware (ITS, tolling and communication) to the overall Maintenance On-Line Management System (MOMS).

3.4.4 EVENT RESPONSE

The TMS will provide logic based central response system that will use the event details and response rules and templates to generate a suggested response for operator confirmation. The system will allow for the detailed tracking of each event – unplanned or planned. This documentation will be required to demonstrate when speeds in the managed lanes fall below 50 mph for reasons beyond the control of the Consortium.

Response mechanisms include:

- Lane Control Signals,
- Dynamic Message Signs and HAR;
Email, SMS, facsimile dissemination to registered subscribers; and

External agency coordination

An operator will be able to modify, approve, and reject any component of a system-generated response plan.

The participation of highway operations personnel (e.g. patrols and recovery units) strategically located throughout the facility will be required. The responsibilities and locations of response personnel will be specified in the Operations and Maintenance manuals.

The TMS response components for the DMS, pagers and external agency coordination are described below, the remaining response descriptions are described in Section 3.4.5.

3.4.4.1 Lane Control Signals

Lane control signals will be deployed along the facility. The TMS will have the ability to control these signals based on any required lane closures. As part of the response logic for each incident, the TMS will have the ability to generate a control plan based upon the location of the blockage and closure and dynamically change lane control signals in response to changing conditions.

3.4.4.2 Dynamic Message and Blank-Out Sign Response

There are two methods that the DMS response function will use to select a DMS or blank-out sign (BOS) message:

- DMS message library logic;
- Algorithmic response logic.

From the systems perspective, a BOS is treated as a limited state DMS. Library messages can be added to the system by any user who has the correct privileges. Library messages can be added to response plans used for manual control of DMS and can be selected for display of scheduled messages. Algorithmic response logic is used by the system to generate responses for events using closure patterns, location of event and distance from devices into consideration. For example, if there is an event that occurs downstream of a sign, then logically that sign would be used to advise motorists of the upcoming event. If a DMS is within the range of an event, then a different type of message would be required, typically one that notifies the motorist where the event ends. DMS that are downstream of events will not be used in an event response.

Response rules and templates will need to be discussed and agreed with TxDOT and take into account state wide signing policies and message priority. For example, TxDOT has a policy of only using DMS to display traffic related information and ensures that incident messages override travel time messages.

3.4.4.3 HAR Response

The HAR function includes the ability to record messages for broadcasting in three ways:

- Operator records a message at the workstation
- Convert text to speech using an embedded commercially available Text-to-Speech engine with the ability to adjust pronunciation to account for local variations.
- Import an pre-recorded audio file in .MP3 or .WAV file format (i.e. amber alert message, TxDOT safety message)

The operator provide with complete play list management to add, remove, schedule, and order all messages at one or multiple HAR stations. It is generally recommended that informational or safety messages are broadcast at all times over the HAR stations.

In manner similar to the DMS responses, the HAR Algorithmic response logic is used by the system to generate responses for events using closure patterns, location of event and distance from devices into consideration. The system will recommend a message. The text to speech engine will generate a recommended message.

Response rules and templates will need to be discussed and agreed with TxDOT and take into account message policies and message priority.

3.4.4.4 Email, SMS, and Facsimile Service

The Email, SMS, and Facsimile service shall comprise message text generated by the event response function according to the message template selected for the response and a proposed list of subscribers that are to receive the generated text, selected based upon the access level specified in the event details. The list of subscribers shall only contain subscribers who are configured for the service. The subscriber list will have the ability to send messages to very classes of subscribers from internal only to the general public as configured.

3.4.4.5 External Agency Coordination

External agency coordination is typically handled through Operations Procedures that outline which agencies (Police, Fire, Ambulance, etc.) need to be notified. This type of coordination can also be facilitated at a system level through an automated incident site management response that provides a list of agencies and phone numbers for contact and allows tracking of when the agency was notified, when they arrived on the scene and when they left. This type of tracking provides valuable information when reviewing historic events to determine operational improvements.

In addition, it will provide valuable information on situation when the speed on the managed lanes falls below 50 mph for reasons beyond the control of the Consortium.

3.5 Information Dissemination to Roadway Users

Dissemination of information to motorists is a key element of an Intelligent Transportation System deployment. This information shall be pushed from the TMS database and disseminated through a number of mediums including:

- Fax/email dissemination to registered subscribers
- Interactive Voice Response (IVR)
- Web site
- Center-to-center sharing with DalTrans and TxDOT
- Texas 511
3.6 Connections to Other Traffic Management Centers

The TMS shall be a Traffic Management Center (TMC) for the project corridor to support mobility equally along both the Managed and General Purpose Lanes. Communication and interoperability shall be achieved with other TMCs in the region, including DalTrans, such that with appropriate privileges, access to data, command, control and information sharing can occur among centers. All communication and access of information shall occur in near real-time within logistical restraints.

3.7 Field Equipment

The sections below outline the high level functional requirements and design approach for the field equipment. Equipment specifications and installation drawings have been provided as examples of types of equipment and installations that will be provided. All of the proposed types of field equipment are available from multiple vendors and have long histories of meeting the demands of the highway environment.

3.7.1 VEHICLE DETECTION

Vehicle detection stations will be implemented at half-mile spacing along both directions of the general purpose and managed lanes throughout the project limits, and include detection on all collector-distributor segments and ramps, including ramps to/from the frontage roads and to/from the intersecting roads. Detector units will be used to measure and collect volume, speed, and lane occupancy data for all lanes of traffic (General Purpose and Managed Lanes). Design and layout of the detector placement with the half-mile spacing will allow collection of data for all ingress and egress to and from the freeway at the interchanges to ensure that all vehicles are accounted for.

The recommended detector technologies for deployment are Frequency Modulated Continuous Wave (FMCW) microwave radar sensors and video image sensors for the depressed managed lanes sections.

Microwave presence vehicle detectors would be side-fire pole mounted installations, with a horizontal detection range of 3 ft. to 66 ft. at a mounting height of 12 ft to 23 ft. Typically each detector unit is capable of providing 8 lanes of detection coverage. Microwave detectors provide reliable data in varying weather and traffic conditions. It is a non-intrusive technology so calibration and maintenance can occur without the need to close lanes of traffic.

The video imaging sensors are also non-intrusive technology, and are recommended for the depressed sections due to limited height and setback distances from the travel way. The microwave sensors require greater height and lateral setbacks than the roadway design for the depressed lanes provides. Since the video sensors must be pointed at the traffic flow, a sensor will be required in each direction of the depressed managed lanes.

The detector units should provide presence accuracy of at least 90% in multiple detection zones, and measure volume, lane occupancy, and speed accurately within 85%, per TxDOT specifications for this type of detector. Data from the vehicle detection sites may be utilized for both ITS and Toll purposes.

The microwave detector is mounted on a CCTV pole or lighting pole, if available, otherwise will be mounted on its own pole. The pole is connected to the equipment cabinet. The equipment cabinet houses the data interface connector and must be located within sight of desired detection zone in order to initially set up the sensors.
The video detector is mounted on the overhead trusses which will also be used to mount the lane control signals. The communications and power lines will come from a lateral duct bank connected to a field cabinet located above ground outside of the general purpose lanes. While this location does not provide sight of desired detection zone, it does provide a far safer environment than placing the cabinet within the depressed lanes.

General requirement for conduit between the detector and cabinet is 2 - 2 inch conduit, 1 conduit for communication and 1 conduit for power. Conduit requirements between cabinet and junction box is 2 – 2 inch conduits, 1 conduit for communication and one spare. There is also a conduit required from the cabinet to the power supply.

3.7.2 CLOSED CIRCUIT TELEVISION CAMERAS

Closed Circuit Television (CCTV) Cameras will be placed at half-mile spacing outside the general purpose lanes along the project limits. Additional CCTV will be required within the depressed managed lane sections with half-mile spacing, and also along each of the elevated managed lanes along IH 35E with half-mile spacing. In each case, the cameras will be positioned on alternating sides of the roadways to provide full coverage of the project limits, including around the interchanges.

The camera unit will provide an NTSC signal, and include digital zoom, auto/manual long-term integration (exposure) control, with built-in frame buffer, auto-focus, and a built-in I.D. Generator, with white letters and black outline. The camera lens should be an f/1.6 or better glass multi-coated zoom lens. The lens must have variable focal length from 3.9 mm to 85.8 mm.

The pan-tilt-zoom unit should provide vertical movement of + 40° to – 90° and horizontal movement of 360° full, contiguous rotation movement. Tilt speed should be at least 20° per sec. and the pan speed must be up to 100° per sec. The unit shall be capable of simultaneous pan-and-tilt movements.

The cameras alongside the general purpose lanes are mounted on a CCTV pole that is mounted on a foundation, and is connected to the equipment cabinet with power and low voltage communication cables. A cabinet, pad mounted or pole mounted, houses the camera control equipment and communication equipment. The cabinet is connected to the closest junction box along the main duct bank, and must be located within 300 ft of the CCTV Pole.

The cameras within the depressed managed lanes will be mounted on overhead trusses which will also be used to mount the lane control signals. The communications and power lines will come from a lateral duct bank connected to a field cabinet located above ground outside of the general purpose lanes.

The cameras positioned on the elevated managed lane sections will be pole mounted on stanchions, with attached equipment cabinets.

General requirement for conduit between CCTV and cabinet is 2 – 2 inch conduit, 1 conduit for communication and 1 conduit for power. General requirement for conduit between cabinet and junction is 2 – 2 inch conduit, 1 conduit for communication and 1 spare. Conduit between the cabinet and power is also required.
3.7.3 DYNAMIC MESSAGE SIGNS

Dynamic Message Signs (DMS) will be located throughout the project corridor, on both general purpose and managed lanes, approximately 1 mile upstream of key decision points and interchanges. The proposed locations include:

- Northbound IH 35E @ one mile upstream of Loop 12 interchange
- Northbound Loop 12 @ one mile upstream of IH 35E interchange
- Northbound IH 35E General Purpose Lanes @ one mile upstream of IH 635 (existing)
- Northbound IH 35E Managed Lanes @ one mile upstream of IH 635
- Southbound IH 35E General Purpose Lanes @ one mile upstream of Loop 12
- Southbound IH 35E Managed Lanes @ one mile upstream of Loop 12
- Southbound IH 35E @ one mile upstream of IH 635
- Eastbound IH 635 General Purpose Lanes @ one mile upstream of IH 35E
- Eastbound IH 635 General Purpose Lanes @ near Josey Lane (one mile upstream of an access point to Managed Lanes)
- Eastbound IH 635 General Purpose Lanes @ one mile upstream of Dallas North Tollway (existing)
- Eastbound IH 635 Managed Lanes @ one mile upstream of exit to Dallas North Tollway
- Westbound IH 635 General Purpose Lanes @ one mile upstream of IH 35E (existing)
- Westbound IH 635 Managed Lanes @ one mile upstream of exit to IH 35E
- Eastbound IH 635 General Purpose Lanes @ one mile upstream of US 75 (existing)
- Eastbound IH 635 Managed Lanes @ one mile upstream of exit to US 75
- Westbound IH 635 General Purpose Lanes @ one mile upstream of Dallas North Tollway (existing)
- Westbound IH 635 General Purpose Lanes @ near Hillcrest (one mile upstream of an access point to Managed Lanes)
- Westbound IH 635 General Purpose Lanes @ one mile upstream of US 75

Driver information displayed on these signs will provide incident notification and travel times, and are placed to allow drivers to choose alternative routes, when needed. Signs will be either gantry or cantilever mounted, depending upon the number of travel lanes and space restrictions within depressed lanes.
It is recommended that LED technology signs be deployed within project limits. The LED DMS should have a walk-in housing and include the sign controller within the sign housing. The sign face should consist of three lines of 25 display modules per line in a line matrix configuration. Each line should consist of an array of seven pixels high by 125 pixels wide to allow for the display of 18-5X7 characters per line with double column spacing between characters. Each line should be at least 18" in height.

The sign controller should be a 19-inch rack mountable Type 170E traffic controller meeting FHWA specifications and with resident software stored in non-volatile memory. The sign controller should be programmed to receive sign control commands from the master controller, transmit responses as requested to the master controller, and control sign operation and message displays in accordance with Special Specification, "National Transportation Communications for ITS Protocol for Dynamic Message Signs."

### 3.7.4 ROADWAY WEATHER INFORMATION STATIONS

A single Roadway Weather Information Station (RWIS) will be located near the critical IH 35E and IH 635 interchange. Pavement sensors will be positioned on elevated sections along IH 35E, elevated sections within the interchange, and along depressed lane sections. These locations are all critical if precipitation or freezing occurs.

RWIS will measure weather conditions such as temperature (air, surface, depressed), precipitation, humidity, wind speed/direction, visibility, and barometric pressure, wind, fog, and precipitation will be measured. Sensors will be placed in the air, in-pavement, or below pavement to collect varying types of weather related data.

General requirements for conduit between the RWIS station and the junction box are 2 - 2 inch conduit, one conduit for communication and one spare. Conduit is also required between the RWIS station and the power supply.

### 3.7.5 OVER-HEIGHT VEHICLE DETECTION SYSTEMS

Over-height vehicle detection (OHVD) systems will be located in advance of access points to depressed managed lanes, due to the height restrictions, along with blank-out signs (BOS) to issues warnings to any vehicles surpassing these restrictions. The BOS will be smaller size cantilever-mounted DMS with ability to warn over-height vehicles of pending height restrictions upon triggering the OHVD. The BOS will be located in close proximity downstream of the OHVD. The OHVD and BOS will be positioned to allow over-height vehicles to exit prior to entrance of depressed lanes, or pull over if no exit is practical in order to turn vehicle around.

The OHVD is mounted on a CCTV pole or lighting pole, if available, otherwise will be mounted on its own pole. The pole is connected to an equipment cabinet. The equipment cabinet houses the data interface connector and should be located within sight of desired detection zone in order to initially set up the sensors.

Additional information on OHVD is found in Section Error! Reference source not found.

### 3.7.6 LANE CONTROL SYSTEMS

Lane control signals (LCS) positioned along depressed managed lanes with quarter-mile spacing, and on approaches and access ramps to depressed managed lanes to assist motorists with highly
visible lane control information. The proposed spacing assures continuous visibility for all motorists at all times.

An LCS will be mounted over each travel lane and shoulder lane if wide enough for vehicle passage. The LCS units will be MUTCD compliant. Each LCS unit will be mounted on an overhead truss within the depressed lanes, and on overhead gantries outside the depressed lanes.

The communications and power lines will come from a lateral duct bank connected to a field cabinet located above ground outside of the general purpose lanes. General requirement for conduit between the detector and cabinet is 2 - 2 inch conduit, 1 conduit for communication and 1 conduit for power. Conduit requirements between cabinet and junction box are 2 – 2 inch conduits, 1 conduit for communication and one spare. There is also a conduit required from the cabinet to the power supply.

3.7.7 SUMMARY OF FIELD EQUIPMENT LOCATIONS

The design schematics provided in Appendix A show the ITS proposed equipment locations throughout the project corridor. Where different types of equipment are located in close proximity, the cabinets and other civil provisions such as cable pull/splicing facilities may be consolidated where practical. These locations are preliminary and may need to be modified due to horizontal and vertical alignment.

4. DEPRESSED MANAGED LANE SYSTEMS

4.1 Field Equipment Requirements

4.1.1 EMERGENCY RADIO

The Emergency Radio system will provide voice communications for emergency services (police, fire, ambulance) and maintenance vehicles in the depressed managed lanes. There is an expectation that that signal from existing emergency radio system surface transmitters and repeater sites operating in the 800 MHz public safety radio band will not provide sufficient penetration into the depressed roadways, so signal levels will be too low to provide reliable communications. The emergency radio system will thus provide a repeater system for the roadways below the surface.

The repeater system will utilize a leaky coax (radiating cable) transmitter, installed along one wall of the depressed roadway, with bi-directional amplifiers (BDA’s) installed at regular intervals to ensure adequate signal level throughout the depressed roadway. The system will modulate voice communications onto a dedicated fiber optic transmission path feeding the BDA’s.

Transmission of emergency information to motorists will utilize a Highway Advisory Radio system operating on a separate licensed AM channel (e.g. 530 kHz, 1510 kHz, as established by FCC CFR Part 90.242), or using a low-power FM transmitter if a license can be obtained (see http://www.fcc.gov/mb/audio/lpfm/index.html). Because the depressed managed lanes are open to the surface, a commercial AM/FM radio emergency override system for the depressed managed lanes can not be deployed as it would interfere with the commercial radio systems at the surface.

4.1.2 OVER-HEIGHT VEHICLE DETECTION

The Over-height Vehicle Detection system (OHVD) consists of two principal subsystems: the detector and warning sign. The OHVD detector consists of two detector “heads” each containing a
transmitter and receiver; with each transmit/receive pair using a different light wavelength (e.g. red and infrared). The detectors are connected to both an electronic warning sign (Blank-Out Sign – BOS) located “downstream” and to the control center to generate an alarm for operations staff. Operations staff can then confirm the alarm by checking the video camera that covers the approach roadway. When triggered, the BOS will display a warning message, either directing the over-height vehicle to avoid the depressed lane roadway or to stop, if on an entrance ramp to the depressed lanes. The BOS will be installed at downstream distance determined by the operating speed of the roadway and sign legibility distance to allow for reading and reaction time. BOS may be installed either on an overhead gantry or cantilever structure to provide a completely unobstructed view to motorists.

OHVD’s will be installed on all approach roads leading to height-restricted roadways, but not in the depressed roadway itself. Since some approach roadways may have traffic operating in both directions, the OHVD detectors are configured to produce an alarm and trigger the BOS only if the dual beam is broken in a particular sequence. The detectors will have the capability to detect pipes and other small apparent area objects that may be loaded inappropriately in a vehicle and that may cause substantial damage to equipment installed on overhead gantries in the depressed roadways.

The OHVD detectors will be installed on poles situated on both sides of the approach roadway, and at relative heights to ensure that the detection beams are parallel with the super-elevation of the road. Power and communications cabling will be provided to both detector heads, with one side connected to the fiber optic communications backbone for transmission of alarms to the control center. A direct connection between the detector and BOS will also be installed to allow the detector to trigger the BOS.

4.1.3 TOLL EQUIPMENT

Toll equipment, described elsewhere in this document, will be installed in the depressed managed lanes at the toll zones transition locations. Toll equipment will be installed on an overhead gantry.

4.1.4 ITS EQUIPMENT

ITS equipment, consisting of CCTV surveillance cameras, pavement sensors, lane control signals, vehicle detectors, and general purposed dynamic message signs will be installed at various locations in the depressed managed lanes.

CCTV cameras (C) will be installed either on overhead gantry structures or attached to the side walls of the depressed roadway. Cameras will typically be oriented to look downstream, to minimize accumulation of dirt and soot on the camera enclosure lens, but will have full pan-tilt-zoom capability to support surveillance requirements supporting incident response and security. Video, control and power cabling from the camera head will be fed from a small camera cabinet located nearby, and which provides the interconnect to the fiber optic communications network and power distribution system.

Pavement sensors (P) will be installed in the depressed roadway specifically to identify icing conditions since the depressed lanes will be shaded from direct sun.

Lane Control Signals (LCS) will be installed on overhead gantry structures at quarter-mile intervals in the depressed roadway to support traffic management, particularly in response to incidents and maintenance activities in the roadway. Communications and power cabling will be fed from nearby cabinets installed at the surface level (where possible) to facilitate access for maintenance (cabinets installed in the depressed lanes would require a lane closure for any maintenance activities, disrupting traffic flow).
Vehicle detectors (V) will be installed on the same overhead gantry structures as the lane control signals to collect traffic flow information (volume, lane occupancy, speed, link travel time) in both directions of the managed lanes. As with the Lane Control Signals, data and power cabling for the detectors will be fed from nearby cabinets installed at the surface level.

Dynamic Message Signs (DMS) will be installed in the managed lanes on overhead structures upstream of major interchanges: on the eastbound side, upstream of the last exit ramp before the DNT interchange, and on the westbound side, upstream of the last exit ramp before the IH-35E interchange.

The ITS equipment is described in more detail elsewhere in this document.

4.1.5 COMMUNICATIONS

Communications with equipment in the depressed managed lanes will generally consist of an electrical (copper) connection from the equipment “head” to a nearby controller cabinet, where signals will be interfaced to the fiber optic communications backbone. Circuit and cabling types of each of the general equipment types are identified in the following table:

<table>
<thead>
<tr>
<th>Device</th>
<th>Circuit Type(s)</th>
<th>Cabling</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCTV (video)</td>
<td>NTSC (analog)</td>
<td>Coax (e.g. RG-59, RG-11 depending on distance, signal attenuation)</td>
</tr>
<tr>
<td>CCTV (control)</td>
<td>Serial (EIA-422)</td>
<td>STP (2 pair)</td>
</tr>
<tr>
<td>OHVD</td>
<td>EIA-485, EIA-422</td>
<td>STP (2 pair)</td>
</tr>
<tr>
<td>Electronic signs (LCS, BOS, DMS)</td>
<td>Serial (EIA-485, EIA-422) or Ethernet</td>
<td>STP (2 pair)</td>
</tr>
<tr>
<td>Pavement Sensor</td>
<td>Custom (analog)</td>
<td>STP (2 pair)</td>
</tr>
<tr>
<td>Vehicle Detectors (microwave)</td>
<td>Serial (EIA-485, EIA-422 or Ethernet)</td>
<td>STP (2 pair)</td>
</tr>
<tr>
<td>Vehicle Detectors (video)</td>
<td>NTSC (analog)</td>
<td>Coax (e.g. RG-59, RG-11 depending on distance, signal attenuation)</td>
</tr>
</tbody>
</table>

All copper communications cabling must terminate on properly grounded transient suppression devices (e.g. Edco CX-06-BNC-Y for video, PC-642C-008 for 422/485 circuits) in the roadside control cabinets prior to connection to communications equipment.

Specific communications requirements for each of the devices are described in Section 7.

4.2 Device Monitoring and Control

There are two paradigms for monitoring and control of equipment in the depressed managed lanes: one to support operations (e.g. surveillance and incident response), and the other to support maintenance. For both, equipment in the depressed lanes will be monitored and controlled from the control center. Operators in the control center will have the ability to control cameras (pan, tilt, zoom, picture quality, etc.), control the display state of lane control signals and toll rate signs, display messages on dynamic message signs, and control the messages broadcast from the HAR system. Operators will also have the ability to monitor alarms from over-height vehicle detectors, monitor traffic flow data from vehicle detectors, and monitor road surface conditions from pavement sensors.

From the maintenance perspective, ITS equipment providing an Ethernet interface will support simple network management protocol (SNMP) queries to allow the control center systems to obtain periodic information on the operational status of the equipment. Thresholds for specific parameters
associated with each device type will be established and alarms generated for conditions that fall outside of the configured thresholds. The system will also poll all equipment on regular intervals to monitor communications to the equipment. For non-Ethernet equipment (e.g. equipment with serial interfaces) that does not provide an SNMP interface, device monitoring will extend as far as the media converter that interfaces the device to the Ethernet network.

4.3 Event Response

Since the roadway geometrics in the depressed managed lanes are confining, the design of the ITS elements for the depressed roadway must allow for and support special incident response strategies (e.g. contra-flow). A traffic incident occurring under relatively light traffic volume conditions will result in closure of the affected lane or lanes, with upstream LCS and overhead DMS (where available, depending on the location of the incident) used to warn motorists of the lane closure. LCS will also be used to warn of lane closures associated with maintenance activities in the roadway (which will only be undertaken when traffic is light). If a major traffic accident occurs under high traffic volume such that emergency response vehicles will not be able to access the accident site from the upstream side, LCS and overhead signage will be used to facilitate contra-flow access to the scene.

4.4 Ambient CO and NOx Measurement

Air Quality Monitoring cabinets will be installed at ground level at the IH 635/IH 35 interchange and at the IH-635 Dallas North Tollway interchange. The AQM cabinets (~18” x 48” x 48”) will be equipped with CO and NOx detection, along with wind speed and direction to allow assessment of the source of pollutants. The AQM cabinet includes a serial communications interface that will be connected to the communications backbone using serial to Ethernet conversion. Each of the cabinets will be provisioned with calibration gas cylinders to allow for periodic auto-recalibration to maintain measurement accuracy. Power provisioning will consist of a 20 amp 120 V circuit (1.2 kW dissipation) to provide sufficient power for sensors and internal cabinet environmental conditioning. The AQM equipment will support remote monitoring using vendor software at the control center to poll the field equipment for data and compile reports.

5. INTEGRATED SYSTEM COMPONENTS

There are several common components of the ITTMS that encompass both the TCS and ITS. These components are described below.

5.1 Interface to Project Web Site

The ITTMS shall provide information to the Consortium’s project web site to communicate information about the ML project to the public. During construction, the web site would post such information as construction alerts, weather alerts, detours, delays and regular updates on the project schedule and overall progress. These alerts could be posted by an operator at the TMC. The project web site is also one of the required media for publishing the ML toll rate schedule. The web site could be integrated with the toll and ITS systems to provide real-time and historical dynamic pricing information, CCTV camera images, and traffic flow. Data from the weather station and ice detectors could also be posted.
5.2 Maintenance Online Management System (MOMS)

The MOMS will allow for monitoring and control of equipment failures within the ITTMS. The system will be the focal point for all toll system maintenance activities including routine preventative maintenance, corrective maintenance, real-time monitoring, repair calls and report generation. The system will accurately provide system status information on a real-time basis.

The system will be capable of providing the following information to its users:

- Current System Status;
- Lane Operation Status;
- Failure and/or Malfunction Location;
- Failure and/or Malfunction Description (including priority level);
- Spare Inventory Quantity;
- Part/Equipment description (including part/serial no.) (if applicable);
- Record of last maintenance activity for a part entered by maintenance staff;
- Record of last preventative and corrective maintenance activity for a part as entered by maintenance staff; and
- Historical system information/report generation.

The consolidation of equipment status for tolling, ITS, and related communications infrastructure hardware provides a single source of information for the maintenance staff. All transportation technology items are monitored from one source allowing for maintenance efficiencies through better deployment of field staff and consolidated monitoring.

5.2.1 WORK ORDER GENERATION

The subsystem will be designed with the ability to generate work orders with little or no human intervention. The subsystem will provide for generating, at a minimum, four (4) different types of work orders (Ad Hoc, Preventative Maintenance, Corrective Maintenance, and Emergency Maintenance. The work order will record the source of the work order, either as automatically triggered by MOMS monitoring, or the person reporting the failure. The subsystem will provide for the capability to build ad-hoc work orders for unusual occurrences of maintenance activities, as well as blank work orders for repairs or malfunctions not directly reported by the MOMS.

5.2.2 WORK ORDER RESPONSE

The subsystem will allow both automatic and manually activated paging of technicians once a work order has been generated. The subsystem will use a set basis of Severity Levels to determine the required response and repair time.

The paging process will check to determine the assigned active technician and updates the dispatch record to include the new service call.
The subsystem will monitor the disposition of service calls and will generate an alert for any work order not responded to or repaired within the required time.

5.2.3 REMOTE ACCESS

The subsystem will be designed with the capability to allow technicians and/or other users to gain access from a remote location. The dial-up access will be designed to utilize simple dial-up connection tools typically found on laptop computers. Access will be password-protected to prevent unauthorized users from gaining access. Each user will use a personal password when logging into MOMS.

5.2.4 INVENTORY AND PARTS CONTROL

The system will include an integrated spare unit and spare parts inventory control function. This function will be integrated with the Work Order generation function, in order to automatically update and maintain the system and spare parts inventory based on Work Orders and technician recording of parts used during work order closeout.

5.3 Performance Measures and Reporting

The ITTMS shall provide an operations and managerial reporting and query function for both pre-defined and ad-hoc reports that support the performance analysis of the ML project. Users would browse, choose, and run reports through a clearly displayed and user-friendly interface that supports a variety of viewing, printing and saving formats, including on-screen, Postscript Document Format (PDF), HyperText Markup Language (HTML), comma-separated values (text), and Microsoft Excel™.

The TCS reports shall enable review of performance measures with applicable data provided for each performance standard required by TxDOT. Specific reports should be designed to meet the monthly and weekly performance reporting requirements.

As required by Exhibit 4 of the CDA, the Consortium shall measure and report average speeds on a “rolling per minute basis” for each 24 hour period. The ITTMS shall generate these reports for selected time periods, and list any periods for which the average speed fell below 50 mph, along with the reason for the reduced speed and any corrective action taken. The system shall also provide a HOV/motorcycle transaction report for a given month, including whether these transactions have been confirmed by TxDOT, and the total amount potentially due for reimbursement to the Consortium.

Additionally, the system shall provide, at a minimum, the following general report types:

- Revenue Reports
- Audit Reports
- Reconciliation Reports
- Traffic Reports
- Equipment and Lane Reports
- Transaction Reports
• Maintenance Logs and Replacement Activity Reports

5.4 Data Storage and Archival

The ITTMS shall archive older toll and traffic data to a media source for possible future retrieval, processing or printing. The media with archived data shall be held for a period that complies with State and Federal data retention laws and privacy requirements. Detailed Transponder and Video Transaction and activity data should be available for at least eighteen months (video tolls should be available until they have been satisfied, i.e., paid or dismissed).

5.5 System Backup

The ITTMS database(s) shall include software that allows the user to configure the scheduling of backups, and these backups should be performed while the databases are active (i.e., hot backup). The backup option shall be Storage Area Network (SAN) or Network Area Storage (NAS) based and shall have the capacity to backup the database in its entirety and shall accordingly allow for future expansion.

Backups should be performed no less than once per day and should not interfere with the normal operation of the system or running of reports.

The backup data should be stored at a secure off-site location.

5.6 Accounting for System Redundancy

Key elements of the transportation technology systems will be equipped with built in redundancies to reduce the potential for disruptions in keeping with good toll and ITS industry practices. The primary focus of these design features is on the toll system. The loss of a camera or vehicle detector is not as detrimental to on-going revenue operations. The toll system has been redesigned to almost remove any single points of failure. The measures noted below will be also be supported by a comprehensive preventative maintenance program that will monitor and replace suspect components. Key redundancies include:

• Toll Transactions: The near perfect recording of the passage of every vehicle past a tolling point is a critical objective of a toll collection system. But once this event (either toll transaction or violation) is captured, the information must reliably be transferred from the lane level through the plaza level to the host level for processing. The system design must have the ability to store information at the lane level until the transfer of the data is confirmed at the central system. The lane level must be able to store transaction information for at least 30 days in case communications to central system are disrupted. Thirty days is in keeping with common toll industry practice

• Lane Controller: The lane controller will be configured as a dual redundant processor with dual hard drives with automatic fail over to reduce the potential for disruptions at the lane level. Each tolling point will incorporate UPS that will provide power for up to one hour. This approach exceeds common toll industry practice, but many newer systems are using this design.

• Transponder Readers and Cameras: The proposed configuration for the tolling point equipment includes overlapping transponder antennas and image capture cameras. If one fails, the others would provide limited coverage at the tolling point. If readers fail, then video images can be captured. The images would be checked to identify existing
transponder account holders. The overlapping of reader zones and cameras is a common and proven approach.

- **Central Systems:** The Central Servers will be equipped to provide redundancy and fault tolerances in keeping with IT industry practice using devices such as:
  - Redundant services with automatic fail over;
  - RAID disk system;
  - Redundant power supply;
  - Hot-swappable hard disks.
  - The central servers will have the capacity to retain all data at the detailed transaction and incident level for a minimum of one (1) year.
  - Transaction data storage requirements will be estimated based on traffic volumes.

- **Communications System:** The communications architecture is based on an Ethernet network configured in a modified hub configuration. Each Ethernet node in the network will have two high-speed connections to the backbone, a primary one to the central node at the administration center and a secondary one to an adjacent node. In addition, the elevated and tunnel configuration of the roadways requires that conduit runs be provided in both the managed and general purpose lanes. This parallel conduit system provides redundant paths for communications if one link is interrupted. This multiple redundancy of paths generally exceeds common communication architectures.

- **Enforcement Light:** Signals would be installed at each tolling point for both HOV and SOV lanes, and triggered to turn on when valid transponder is NOT detected on a passing vehicle. This would provide a visual cue to a law enforcement officer that the passing vehicle did not pay a toll. The enforcement light and associated cable is a single point of failure in the toll system design. The design will incorporate a LED light that has an inherently long mean time between failures. The status of the light will be monitored by the lane controller and MOMS. And finally, the preventative maintenance program will replace the LED light before it is anticipated to fail. Given the 99.9% performance requirement, this item will be a special focus of the maintenance staff.

### 6. SAFETY SYSTEMS

#### 6.1 AM/FM Rebroadcast

Because the depressed managed lanes are open to the surface, a commercial AM/FM radio emergency override system for the depressed managed lanes should not be deployed. Reception in the depressed section should be acceptable. The installation of a rebroadcast system could cause interfere with the commercial radio systems and defeat the its intended purpose.
6.2 Voice Communications

The voice communications system will use the existing public safety radio network on surface and elevated roadways. Safety and security personnel will use either in-vehicle mobile radios, or handheld portables. In the depressed roadways, security personnel will use the repeater system to connect to public safety radio network. This equipment is described in Section 5.1.1.

6.3 Alarm and Access Control Systems

Roadside equipment cabinets will be equipped with door sensors and an alarm transmitted to the control center whenever an equipment cabinet door is opened. This information will be logged and correlated with maintenance activities (e.g. work orders), Access control systems will be installed at the control center(s) to restrict access to authorized personnel and maintain records of personnel access. Access control systems may be utilized either or a combination of proximity card readers or biometric scanners (e.g. palm/fingerprint scanner) tied to magnetic door interlocks.

6.4 CCTV Security Cameras

The CCTV cameras installed for monitoring traffic in the managed and general purpose lanes will also be used for security surveillance functions, and no dedicated security cameras will be required. Security cameras will be installed at the control center to monitor the entire facility perimeter, all access doorways, and parking areas. Perimeter monitoring will utilize cameras installed either on the roof of the facility, or, if required to address occluded areas, on camera poles connected directly back to the facility.

7. COMMUNICATIONS INFRASTRUCTURE

7.1.1 ELECTRONIC TOLL COLLECTION SYSTEM

Communications requirements for the electronic toll collection system are driven largely by two factors: high bandwidth for transmission of video and imagery and low latency for transmission of data between the field sites and control center(s) for any required transaction processing. A minimum of 50 Mbps communications bandwidth will be allocated for each electronic toll collection site.

7.1.2 ITS FIELD DEVICES

Of the ITS field devices, CCTV surveillance cameras drive the communications requirements more than any device type. Video from CCTV surveillance cameras will be encoded as IP for transport over the Ethernet network. To ensure good image quality at the control center(s), a minimum of 6 Mbps will be allocated for each video signal. All remaining ITS field equipment device types, including vehicle detectors, DMS, LCS, OHVD, and RWIS require very limited bandwidth.

7.1.3 DEPRESSED MANAGED LANE SYSTEMS

The only unique system in the depressed managed lanes is the public safety radio repeater system, and it will require a dedicated set of fibers to interconnect a base station, located at the control center, to optical-to-electrical converters and bi-directional amplifiers driving the leaky coax transmitter in the depressed lanes. The fiber dedicated to this system will carry an analog voice signal.
7.1.4 REDUNDANCY OF NETWORK

The communications network must provide extremely high reliability as it supports a number of critical systems, including public safety radio in the depressed managed lanes, revenue systems (toll transaction information), and motorist safety systems. To achieve the required level of reliability, the network is designed around a fully path diverse fiber optic ring for both the managed lane roadways and general purpose roadways, along with redundancy in the communications equipment such that no single point of failure results in the loss of system functionality.

7.2 Communications System Architecture

7.2.1 OVERVIEW

The communications system architecture will consist of dedicated fiber optic communications backbones for the Managed Lanes and General Purpose Lanes, with each backbone carried on physically distinct fiber optic cables. For both the Manage Lanes network and General Purpose Lanes network, the architecture of the core backbone communications network will consist of a fault-tolerant Ethernet (IP) network utilizing redundant network components (e.g. switches, routers) and a fully path-diverse fiber optic ring topology. The network components will comply with applicable IEEE standards for network reconfiguration in the event of a link failure (e.g. IEEE 802.1d or 802.1w).

Field equipment will connect to the backbone at nodes equipped with a backbone Ethernet switch. Node cabinets will be equipped with data aggregation devices (e.g. terminal servers for aggregating multiple serial circuits onto an Ethernet channel, Ethernet switches for combining various Ethernet devices onto the network) and media conversion to convert between electrical and optical domains. All video and data will be encoded and transmitted as IP on the Ethernet network.

All fiber optic cables will be installed in an underground conduit system or embedded in elevated roadway structures.

At the control center(s), individual video and data circuits will be distributed from the Gigabit Ethernet backbone and connected to ATMS and video display equipment. Serial data and control circuits (e.g. sign control circuits) will be accessed using terminal servers. IP-video on the Ethernet backbone will be decoded for display for operators (e.g. on a desktop video display or video display wall).

7.2.2 HIGH SPEED BACKBONE

The High Speed Backbone will utilize fault-tolerant Gigabit Ethernet over fiber with backbone nodes connected in a fully path diverse ring. Backbone nodes will be equipped with Gigabit Ethernet switches capable of rerouting communications in the event of a link failure.

7.2.3 NORTH TEXAS REGIONAL ITS COMMUNICATION SYSTEM

A dedicated fiber optic cable will be installed in the conduit system to support the North Texas Regional ITS Communication System.

7.2.4 LOCAL DISTRIBUTION

Local distribution circuits provide the connections between field equipment sites and the communications backbone. The local distribution circuits will consist of a combination of Ethernet
and point-to-point connections between field equipment sites, local controller/communications cabinets and backbone nodes. Local distribution circuits will “collect” data and video from a number of field sites for aggregation (multiplexing) and insertion onto the backbone.

7.2.5 INTERCONNECTIONS

The network topology and architecture will be provisioned to support interconnection of the communications network to other fiber networks.

7.3 Outside Plant

7.3.1 CONCEPTUAL LAYOUT

The conceptual layout of the conduit system is shown schematically in Appendix A.

In general, the conduit systems parallel the managed and general purpose lanes. Where the managed lanes are on elevated roadway (viaduct), communications (and power) conduit will be installed in the road structure (e.g. in the barrier, or beneath the roadway inside a box girder), and the conduit for the general purpose lanes will be installed in a trench beside the roadway. Since the communications topology is designed to provide full path diversity, conduit systems will be installed in both directions of both the managed lanes and general purpose lanes.

7.3.2 CONDUIT SYSTEM

The conduit system supporting the communications network will consist of 4-4” Schedule 40 PVC pipes (or PE conduit with equivalent rating, e.g. SDR-11) for the communications cabling for Managed Lanes and General Purpose Lanes. Nominal designations for each group of four conduits will be (1) backbone cable, (2) distribution cable, (3) North Texas Regional ITS Communication System backbone, and (4) spare/expansion.

7.3.3 MAINLINE CONDUIT

The mainline conduit will be installed to parallel the Managed Lanes and General Purpose Lanes. Along IH-635 where the Managed Lanes (ML) are depressed beneath the General Purpose (GP) Lanes, the conduit will be installed in a trench between the GP lanes and frontage/collector roadways.

7.3.4 CROSS ROAD CONDUIT

Where the conduit system crosses existing roadways directional drilling or jacking and Schedule 80 PVC (or similarly rated PE conduit) will be required.

7.3.5 BREAKOUT CONDUIT

Breakout or distribution conduit will consist of a single communications conduit sized to support the communications cables required to connect from mainline node cabinets to equipment sites along the side of the roadway. To facilitate cable management within the conduit and allow for later installation of additional cable to support future equipment requirements, multi-cell flexible fabric innerduct will be installed. Notionally, breakout conduit will emanate from the backbone node cabinets, and provide a cabling path to a set of equipment in the managed lanes or general purpose lanes.
7.3.6 CABLE VAULTS

Cable vaults will be required where-ever the mainline conduit system splits to service the managed and general purpose lanes, for example, on IH-635 east of the IH-35E interchange and on IH-35E north of Loop 12. Cable vaults will also be required at the project limits, and locations where access to all of the various communications cables is required, for example, at the control center locations.

7.3.7 PULL POINTS

Pull points will be installed at regular intervals along the mainline conduit system, determined in part by road crossings (required on each side of a road crossing), required cable access points in the breakout or distribution conduit for connections to equipment locations, and maximum rated cable pulling tension given the specific geometry of the conduit path. Pull boxes will be sized based on the number of connected conduits, slack cable storage, and minimum cable bend radius (largest radius).

7.3.8 FACILITY ENTRY POINTS

Optical Cable Entrance Facilities will be provisioned at the control center(s) to transition from Outside Plant fiber cabling to the building fiber systems and to provide access to all fiber optic communications circuits.

7.4 Fiber Optic Cable

Single mode fiber optic cable will be used throughout the project.

7.4.1 MAINLINE CABLE

The mainline (backbone) fiber optic cable will consist of a 24-strand single mode fiber optic cable for each of the managed lane and general purpose lane roadways. The cables will connect from node to node along each roadway. Since the mainline (backbone) cable is to be dedicated to transport of Gigabit Ethernet, the number of fiber strands can be kept to a reasonably small count, while still allowing for extension of the network beyond the current project limits.

7.4.2 BREAKOUT CABLE

The breakout or distribution fiber cable will consist of a 96-strand single mode fiber optic cable used to interconnect equipment sites and field cabinets with communications backbone nodes. Since the breakout cable will be used to provide largely point-to-point connectivity between field equipment and the backbone nodes, more fiber strands (relative to the backbone fiber) will be required.

7.4.3 CABLE SPlicing

All fiber optic cable splicing will utilize fusion splice methods. Mainline cable butt-end splices will be required to interconnect mainline cable segments and span the entire project area. Mainline splices may occur in underground splice closures stored in appropriately sized pull boxes or cable vaults with slack cable storage. Mainline splices may also be performed in outdoor cabinet splice closures where a field equipment cabinet (backbone node) is conveniently located. Similarly, splicing and
breakout for the distribution cable may occur in underground splice closures or field cabinet splice closures.

7.4.4 FACILITY TERMINATION POINTS

At the project limits, backbone and distribution cable will be terminated in underground splice closures stored in cable vaults to support connection to future extensions of the network.

7.5 Transmission Equipment

7.5.1 DATA COMMUNICATIONS

7.5.1.1 DMS Communications Subsystem

DMS will be configured either with a direct Ethernet interface module, or will be equipped with a serial-to-Ethernet converter and media converter to connect to the Ethernet fiber backbone.

7.5.1.2 Vehicle Detection Communications Subsystem

The vehicle detectors will be configured either with a direct Ethernet interface module, or will be equipped with a serial-to-Ethernet converter and media converter to connect to the Ethernet fiber backbone.

7.5.1.3 LCS Communications Subsystem

The lane control signals will connect to a local control cabinet using serial communications (e.g. EIA-422 or 485 circuits over STP cable) where the individual circuits will be combined onto an Ethernet channel using a small terminal server. The terminal server will connect back to the nearest backbone node on an Ethernet over fiber connection on distribution fiber cable.

7.5.1.4 OHVD Communications Subsystem

The over-height vehicle detection sites will connect to the managed lanes backbone using a serial-to-Ethernet converter and media converter for connection to the fiber optic distribution cable.

7.5.1.5 RWIS Communications Subsystem

The road-weather information system controller will be configured either with a direct Ethernet interface module, or will be equipped with a serial-to-Ethernet converter and media converter to connect to the Ethernet fiber backbone.

7.5.1.6 ETCS Communications Subsystem

The electronic toll collection system equipment will connect to a local control cabinet equipped with an Ethernet switch, which will be connected to the distribution fiber cable and to the nearest backbone node cabinet.

7.5.2 VIDEO COMMUNICATIONS

7.5.2.1 CCTV Communications Subsystem

Video and control circuits for CCTV cameras will be connected over copper (coax and STP cable, respectively) to a local control/communications cabinet equipped with a video encoder to generate IP video for transmission as Ethernet. A media converter will be used to connect the encoder to the distribution fiber cable and to the nearest backbone node cabinet.
7.6 Security Communications

Door alarms on field equipment cabinets will be connected using a discrete to serial converter and then to a port on the Ethernet switch located in the cabinet. In the control center(s), door alarms, access control and intrusion detection systems will all be connected to the building LAN(s) and monitored by a central security system. Events that trigger alarms will be verified using the CCTV system, and a response established accordingly.

8. BUILDINGS AND FACILITIES REQUIREMENTS

This section provides the building and facility requirements for the Administration Building to support the operations and maintenance of the toll, ITS, and communications infrastructure including the Operations Control Center (OCC). The OCC will be located in the Traffic Management Center (TMC) control room.

The Administration Building shall function as the center for toll and traffic operations and shall be located within five miles of the IH 635/Dallas North Tollway interchange. The building shall require enough space to accommodate the TCS operations, transportation technology maintenance operations, and administrative needs for the toll corridor.

8.1 Operational Requirements

The following operations should be accommodated in administration building:

- Toll Collection Operations: The operations staff will be responsible for monitoring and managing the toll collection aspect of the project including manual image review and validation, calculation and collection of toll amount due, secure, encrypted interface with allied organizations and tolling authorities (including NTTA), and liaison with law enforcement and court staff. Typical office cubical spaces are adequate with appropriate conductivity to the toll collection system.

- Systems Administration: A staff of system analysts will be required to maintain the software applications and will require standard office space with appropriate conductivity to the toll collection system.

- Traffic Operations: This staff would monitor and operate the facility using the traffic management system software application and the field monitoring elements of the toll collection system which would provide them with the Operations Control Center (OCC). The traffic management center control room should include the provisions for operators workstations, supervisor’s workstation, and a large video display wall.

- Maintenance: Internal staff will provide maintenance services on a 24/7 basis. Maintenance technicians will be on duty at all times. A small workshop, spare parts storage, file space, desk space for the two supervisors, and secure parking for vehicles will be required.
8.2 Building Spatial Requirements

Based on the operational requirements, the following spatial requirements have been identified for office spaces. The approximate size of these required office space is provided but to account for common spaces, support spaces and circulation, an additional 125 square feet per person is a common GSA standard. These spaces include conference rooms, rest rooms, break rooms, etc.

- Enclosed Offices: One enclosed office of approximately 120 square feet is required for the program manager.

- Program Administrative and Systems Staff: These seven staff should be located in cubicles spaces of approximately 90 rentable square feet.

- Toll Collections Operations: These eight staff should be located in cubicles spaces of approximately 90 rentable square feet. This staff should be located in a separate room from the other office spaces because of the interactive nature of their work tasks could be disruptive to the systems and administrative staff.

The Control Room houses the traffic operations staff and required equipment for the day-to-day operation. The control room shall contain sufficient room for three workstations, accommodating many flat-screen monitors and other equipment, and a Central Display System or Video Wall. The large screen display, which shall be the focus of the Control Room, shall be comprised of at least two cubes that can display up to eight cameras concurrently.

Next to the control room is the Equipment Room. It shall accommodate the following components:

- Equipment Racks shall be situated to provide adequate floor space for easy access to the equipment. Racks shall be accessible from the front and back; aisle clearance between the racks shall be at least thirty-six inches. It is estimated that up to 12 racks may be required. The racks shall include the following equipment:
  - Video Transmission Equipment,
  - Video Switch,
  - Fiber Splice/Termination Shelves,
  - Data Transmission Equipment,
  - IT Network Equipment, and
  - Servers.

- Backboard Area for the installation of patch panels, circuit breakers, etc. shall be included in the equipment room. In addition, the room shall require exterior conduit access for the communications cable to terminate near the backboard.

- Storage Racks shall be included in this room for the system documentation and reference material as well as adequate space for access to stored equipment. Space shall be allocated to the Equipment Room to account for future inclusion of addition ITS systems.
The Maintenance spaces will require work room, desk space, and spare parts storage. The work room should be between 500 and 750 square feet. The spare parts storage space should not be over 200 square feet, but a more detailed analysis should be conducted. The decision to park maintenance in a garage or in secured surface parking would depend on the nature of the site.

8.3 General Building Requirements

8.3.1 ELECTRICAL

Overall, electrical requirements and loading shall be based upon the amount of equipment (CPUs and other electronics) that are to be housed in the building. An electrical loading assessment shall be conducted to evaluate these needs.

An Uninterruptible Power Supply (UPS) shall be included in the building design to accommodate the need to provide power during short-term power outage fluctuations and peaks and to provide power for proper system shutdown during longer power outages. The UPS shall be contained within the Equipment Room and have a two-hour charge life to provide power for critical functions.

A Generator should be considered to provide power for extended electric power outages. The fuel powered generator shall provide adequate power for full functionality for two to three days.

8.3.2 MECHANICAL

The primary mechanical considerations for the overall building and specifically the TMC and equipment room are the heating, ventilation and air condition (HVAC) and fire suppression components.

The HVAC system shall have the capability to maintain a room temperature between 65ºF and 70ºF throughout the year for optimal staff comfort and equipment operation. The Equipment Room shall include HVAC capabilities with humidity control to strictly maintain a humidity range optimal for the housed equipment. In addition, the Equipment Room shall contain a manual override to shut down electronic equipment in the event of a cooling failure with temperatures becoming excessively high. Overall, HVAC requirements will be determined by heat load calculations for the equipment. Considerations must also be made for vent and thermostat configuration and location.

A non-water based system shall be installed for fire suppression to ensure minimal damage to electronic equipment in the event of its use. An audible alarm shall be installed to notify staff in the event of a fire and/or the activation of the fire suppression system.

8.3.3 SECURITY

To control unauthorized access to and with the building, a card reader access system shall be implemented. The system shall provide various levels of security, with higher security and more limited access being allocated to the Control, Spare Parts, and Equipment Rooms.

PTZ (pan-tilt-zoom) dome cameras may be installed within the building to provide monitoring within and around the building.
9. WORK PLAN

The Work Plan in general will follow a systems engineering approach throughout the entire life cycle of the project, from initial mobilization and project kick-off, to final acceptance and project hand-off.

The Work Plan for the Electronic Toll Collection System (ECTS) and the Intelligent Transportation Systems (ITS) involves the delivery of the toll, ITS and communication systems. A Systems Integrator approach is proposed, in which the Integrator is retained to be responsible for design, build and system integration. This approach would have the following key phases:

- **Design**: The system design will advance the conceptual design to the point where all aspects of the project are fully designed and ready for construction. The System Integrator will perform this effort. All equipment and cable installations will be designed and the functional requirements for all software will be finalized. It is expected that the detailed design for the highway sections will be completed in the same time frame.

- **Build**: The System Integrator will be responsible for all installation, integration and testing of the equipment, hardware, and software. The System Integrator will also be responsible for ensuring that toll collection and traffic management software is integrated with all of the field equipment. It is expected that the System Integrator’s software suite will largely be an existing application that will require configuration and minor modification to meet the needs of this system.

- **Testing**: A testing regime has been identified that provides sequential testing of equipment and software in order to help isolate problems and to make troubleshooting easier. These include tests prior to installation, testing of each individual field device and subsystem, overall system testing, and finally, a 60-day live operations test.

- **Training**: Training for all users of the system shall be provided, including customer service representatives, etc. Maintenance and system administration training shall also be provided.

- **Documentation**: Full documentation of the system shall be provided, including detailed documentation of the system design, configuration, training, as-built conditions, operation and maintenance.

9.1 Selecting a Toll System Provider

Multiple toll system vendors have proven their ability to design, develop, integrate and maintain TCS that meet the TxDOT requirements. Both ETC Corporation and Raytheon developed a conceptual TCS design for the SH 121 project. Systems provided by ETC Corporation support transportation reciprocity between geographically dispersed toll facilities, airports, parking, and commercial vehicle operations, and currently collect over 90% of all interoperable tolls in the State of Texas. They developed a thin-client, browser-based toll solution suite, which includes modules for Customer Service Center operations, Video Toll Processing Center, Audit & Reconciliation Host, Reciprocity, Facility Server (Plaza Host), and Lane Controller. They have implemented 74 ORT lanes for Harris County Toll Road Authority (HCTRA) in Houston, Texas, 36 ORT lanes for NTTA and 44 ORT lanes for the Illinois Tollway.

Raytheon has a CDA with TxDOT to provide ORT systems for Texas toll roads, although a system concept was not provided for IH-635. Raytheon has operational ORT solutions at the 407 in Toronto and the Cross Israel Highway. Recently, they have been selected by the Florida Tolling Enterprise to provide their ORT solution.
TransCore, the provider of the eGo™ tags and readers, has implemented ORT systems in Puerto Rico, Washington State and Florida. They have provided back office systems that provide host, plaza, MOMS, customer service, and violation processing functionality in multiple locations across the United States.

In addition, other toll system providers are developing comparable solutions in Texas. They include United Toll Systems (UTS) and Caseta Technologies. The Consortium has a solid set of toll system providers from which a system can be procured that meets TxDOT requirements within the time constraints of the project. For the proposal to TxDOT, the Consortium will indicate that it will procure a qualified system provider who will install and integrate the system within the promised time frame and financial plan.

The procurement approach will follow this approach:

- Upon notice of award, the Consortium would develop a request for proposals (RFP) and associated specifications based upon the conceptual design work done to date.
- The RFP will be distributed to a select set of potential toll collection system providers, including those noted above.
- Proposals will be developed by the providers and submitted to the Consortium.
- A preferred provider will be selected and negotiations completed.
- The provider will then begin the system development process before Notice to Proceed.

9.2 Mobilization

Upon receiving a Notice to Proceed, the Integrator shall facilitate a kickoff meeting with the Consortium. The kickoff meeting agenda shall include a review of the project budget, schedule, and scope, and identification of any documents or materials that the Integrator needs from the Consortium, TxDOT or NTTA in order to begin work.

The Integrator will be required to work together cooperatively with the Design Build (DB) Contractor and any O&M Subcontractors.

The Integrator shall be aware that TxDOT, other Consortium team members, or other civil Contractors (not part of the Consortium team) may be performing work in the vicinity of the project corridor at any time over the duration of this contract. The Integrator shall cooperate with TxDOT, the Consortium, and other such parties in the performance of any concurrent activities.

The Integrator shall coordinate work schedules with TxDOT, the Consortium and other Contractors to ensure the smooth implementation of all project installation/construction activities.

The Integrator shall cooperate with TxDOT, the Independent Engineer, and Governmental Entities with jurisdiction in all matters relating to the work, including Design Work, Construction Work and O&M Work, including their review, inspection and oversight of the design, construction, operations and maintenance of ITS and TCS.

The Integrator shall be required to support, as needed, the Consortium’s public information and communications efforts, as described in Section 3 of the CDA Book 2A.
9.3 Design

The system design will advance the conceptual design to the point where all aspects of the project are designed. All equipment and cable locations will be defined, the key operating parameters of each component will be identified, and the functional requirements for all software will be finalized.

It is expected that the detailed design will be completed in highway sections, as they are required. It will also be structured into various design packages that correspond to the work operations that must be performed. The split between design packages will be determined according to the work operations that are required, but they could be structured as follows:

- Electronic tolling point field equipment/systems;
- Tolling system software;
- ITS/traffic management field equipment/system;
- Central equipment;
- ITS/traffic management software; and
- Communication network.

The detailed design will include:

- Supply & install specifications;
- Layout drawings;
- Wiring diagrams; and
- Cabinet layouts.

The Integrator, through the appropriately qualified and licensed design professionals identified in the Consortium’s Project Management Plan, in accordance with Section 2 of the CDA Books 2A and 2B, shall prepare the ITS and TCS design in accordance with the requirements of the CDA Books 2A and 2B, the System Requirements, and all applicable TxDOT Standards.

The Integrator shall prepare designs, plans and specifications in accordance with the CDA Documents.

The Integrator shall furnish all aspects of the ITS and TCS Design Work and all Design Documents, including design required in connection with the operation and maintenance of the Project and shall install the ITS and TCS as designed, free from defects, and in accordance with (a) Good Industry Practice, (b) the requirements, terms and conditions set forth in the CDA Documents (including the Technical Provisions and Technical Documents), (c) the Milestone Schedule and Project Schedule, (d) all Laws, (e) the requirements, terms and conditions set forth in all Governmental Approvals, (f) the approved Project Management Plan and all component plans prepared or to be prepared there under, and (g) the Construction Documents, in each case taking into account the Project Right of Way limits and other constraints affecting the Project.

It is expected that the design and development effort for the ITS and TCS will be focused largely on configuring the Integrator’s existing ITS and TCS solution to meet the specific requirements and
business rules of the Project. It is not anticipated that a substantial redesign of the Integrator’s existing ITS and TCS solution shall be required.

The Integrator shall recognize the importance of the ITS and TCS to the success of the project, and strive to foster a collaborative, cooperative design process whereby the Consortium’s comments, concerns, and input are acknowledged and responded to in a mutually agreed fashion.

The Integrator shall conduct a two-day system design workshop with the Consortium’s team. The workshop shall be held at the earliest possible date following the kickoff meeting. The purpose of the design workshop is to ensure that both the Integrator and the Consortium are in agreement on how the system design will support the functional requirements. The Integrator and Consortium shall discuss how each system functional requirement should be addressed in the design, using the Integrator’s proposal as a starting point. The outcome of the design workshop shall be a series of annotated, high-level concept and detailed data flow diagrams that capture the design consensus reached at the workshop.

The Integrator shall prepare and submit to the Consortium for approval a System Development Plan. This plan shall indicate all elements of the system development process and shall include, but not be limited to, the following:


b. Software Development Tools.

c. Programming Languages.


e. Configuration Management Plan.

9.4 Software Development and Configuration

The System Integrator will submit a System Requirements Report to the Consortium. Following approval, the Integrator will then develop an Application Software System Design Report for Consortium approval.

It is expected that the System Integrator’s software suite will largely be an existing application that will require configuration and minor modification to meet the needs of this system. The System Integrator will also be responsible for ensuring that their software can integrate the field equipment. Following approval of the Application Software System Design Report, the Integrator will develop the system interfaces and any required customized modules.

During the Development effort, the Integrator shall keep the Consortium appraised of its progress via weekly reports given via email. The weekly reports shall indicate the percent completion of each subsystem under development, any issues encountered, and the resolution plan for such issues. The weekly reports shall also include a three-week look-ahead of upcoming activities, milestones, and projected levels of completion.

In dealing with outside equipment Integrators, the Integrator shall ensure that representative samples of components are delivered early in the development process to facilitate coding and testing of device interfaces. Throughout the design and installation process, the Integrator shall also endeavor to maintain consistent product specifications as product updates are released to the market.
The Integrator shall conduct unit testing on an ongoing basis in the Integrator’s lab facility throughout the software-coding phase as the individual modules are completed. Although the Consortium may not be witnessing these tests, the Integrator shall provide updates detailing the results of the tests and any corrective actions required as part of the weekly progress reports.

9.5 Installation and Integration

The Integrator shall submit an Installation Plan that identifies the approach to installation and covers the major elements of the installation as detailed below.

The System Integrator will be responsible for all installation, integration and testing of the systems. Close coordination with the civil/electrical contractor will be necessary to ensure that deadlines are met and demarcation points for responsibility are clearly defined.

An important aspect of the implementation process will be to coordinate the provisions to be provided for the project by Consortium staff and/or their subcontractors. These include underground conduit, cable access vaults, power, space in buildings, and roadside space for ITS components.

For efficient construction, it will be important to identify these requirements so that they may be included in the highway construction. It will also be important to fit the cable and components of the project into locations along the highway that allow proper operation without conflicting with other components.

The length of the highway and the phases of construction that are involved will require careful monitoring to ensure that a consistent quality of site installation is maintained. Proper inspection is required to verify adherence to installation specifications in order to minimize the level of future maintenance effort and to maximize the life of the installed components.

Materials and equipment required for the toll collection system, ITS and communication system will be procured according to TxDOT standard drawings and Statewide Special Specifications by the System Integrator. These specifications will incorporate the functional requirements determined during the detailed design and other parameters required to specify each component.

To the extent possible, components will be available from a variety of vendors that will be compatible with each other and the cheapest product will be selected. All materials will be required to adhere to environmental conditions that will be specified for the entire project.

In some cases, the procurement process may select a preferred component and recommend the exact options, configuration, and manufacturer. If this is required, it shall be fully justified in terms of function, cost, and standards before the approach is followed.

The System Integrator will also be responsible for ensuring that their software can integrate the field equipment. It is expected that the System Integrator’s software suite will largely be an existing application that will require configuration and minor modification to meet the needs of this system.

9.6 Documentation

Detailed documentation that describes the system design, configuration, training, as-built conditions, operation, and maintenance shall be provided by the Integrator.
9.6.1 SYSTEM DESIGN DOCUMENTS

Written documentation describing the system to be delivered including all equipment and software to be furnished shall be provided. The System Design Specification (SDS) shall include, as a minimum, the following information:

- Overall system schematic and architecture;
- Major assumptions and risks;
- Detailed description of all subsystems and equipment and hardware, including functional description, interface descriptions, communications loading details, material specifications (i.e. environmental, electrical etc), configuration details and installation details;
- Detailed description of all software, including functional description, system interface descriptions, Graphical User Interface descriptions, hardware specifications, availability and reliability figures and configuration details; and,

The System Design Document (SDD) shall be prepared for both the hardware and software system components. The SDD shall include a description of the system and its constraints, as well as the conceptual design for the overall system and subsystems including software, hardware, equipment, and communications.

The Integrator shall provide a functional narrative of the system and subsystem block diagrams, data flow diagrams, report layouts, graphic user interfaces, and any other graphic illustrations to demonstrate the technical adequacy of the system design approach and compliance for system hardware and software with quality assurance, reliability, maintainability, software development, and other requirements of these requirements.

The document shall include at least the following information:

a. Description of the system and constraints.
b. Functional specifications for the system and the sub-systems.
c. Discussion of any design variants and selection of design.
d. Block diagrams for the system and subsystems.
e. Descriptions of the system and sub-systems.
f. Listing of reports.
g. User task flow.
h. User interfaces.
i. Interfaces for all software modules.
j. Interface to all third parties (TxDOT, NTTA, other TMCs).
k. Interface to financial institution.
I. Reporting.

m. Central System hardware and equipment design.

n. Roadside System hardware and equipment design.

o. Communications network design.


The Integrator shall write the SDD to the level of technical detail that will enable the software development team to code and build the system.

The Central System design element of the SDD shall include the layout for servers, workstations, and other required equipment. Detailed equipment cabinet layout and location drawings shall be provided. The equipment design shall include cut sheets for all equipment, including off-the-shelf equipment procured from another Integrator. The equipment design shall include diagrams illustrating the communications and power connections required for each device.

The Roadside System equipment design element of the SDD shall include lane layout diagrams that depict the planned locations for all field devices and related equipment (communications, cabinets, etc.). The equipment design shall include cut sheets for all equipment, including off-the-shelf equipment procured from another Integrator. The equipment design shall include diagrams illustrating the communications and power connections required for each device. The design plans shall comply with all TxDOT requirements.

The communications design section of the SDD shall include the following:

- Conceptual design of the Project-wide communications network.
- Schematics of existing and new infrastructure to support ITS and TCS.
- Backup communications to be provided for all critical communications links.
- A description of communications protocols.
- A description of the message formats for all communication between subsystems.
- A description of the network management and security.
- Peak data rates, data volumes, latency, security, cost, and reliability for each communications link.

9.6.2 INSTALLATION PLANS

The Integrator shall prepare and submit to the Consortium for approval plans and drawings detailing the installation of the physical components of the approved system design in both the Roadside and Central System. Detailed drawings shall be provided for each system element.

The installation plan shall include and define, at a minimum, the following items:

- The proposed installation schedule, detailing phases, and/or installation segments.
• The minimum resource allocation requirement for any installation phase or segment.

• How the Integrator will manage delivery and staging of the ITS and TCS equipment to be installed.

• The order that equipment items are to be installed with estimated durations.

• Any special or unique installation requirements.

• Equipment to be used to perform installation.

• Requirements for lane closures or other maintenance of traffic requirements.

• A detailed component list of each item version number and serial number to be installed.

The Integrator shall submit an Installation Plan that shall comply with all TxDOT requirements.

9.6.3 TEST PLANS

The scope of the Test Plan shall include Factory Acceptance Testing (FAT), Proof of Concept Testing, System Acceptance Testing (SAT), and Operational Testing, and shall clearly state the objectives, test scenarios, and success criteria of each level of testing.

The Test Plan shall also address the overall schedule of testing, sequencing and interdependency of test, test simulators, reporting procedures, and the process for failure tracking, analysis, and resolution.

A Test Plan shall be submitted outlining the elements to be tested under each test, the testing environment and key criteria for each test. The Test Plan shall also include a schedule of testing. In advance of the initiation of each group of tests, test procedures shall be submitted. The test procedures will outline specific tests, expected results and cross reference design documentation as well as the contract specification.

FAT and POP documentation shall be submitted for each type of device. Where the device is a Commercial Off the Shelf product, the FAT may be replaced with a stamped quality certificate.

A SAT shall be submitted for each subsystem. An overall SAT document shall be submitted that shall include an end-to-end system test and cover both hardware and software functions.

The OPT document shall define minor, major and critical failures and the impacts of each on the OPT including test restarts, allowable downtime and process to address failures.

9.6.4 AS-BUILT DOCUMENTATION

The Integrator and any subcontractors shall update the latest drawings with red lines as changes are incorporated during the installation process. At the completion of the installation of the ITS and TCS project, the Integrator shall gather all red line drawings. The red line drawings shall be verified and then incorporated into a final as-built drawing package. This final as-built package shall include installation drawings, shop drawings, and sketches, and other drawing types that may have been used to install the ITS and TCS.
Final documentation shall include drawings of duct layouts, pull boxes, splice enclosures, cable diagrams, wiring lists, cabinet layouts, wiring diagrams, schematics of communications system, outstation equipment, and outstation equipment cabinets.

The Sub-contractor shall provide sufficient documentation to reflect "as supplied" conditions and to facilitate operation, maintenance, modification, and expansion of the equipment or any of its individual components.

The SDS shall be updated to include the as-built conditions.

The as-built documentation shall be provided 3 weeks after the System Acceptance Test (SAT), and updated documentation will be required at any time software or hardware upgrades are provided.

9.6.5 OPERATIONS AND MAINTENANCE DOCUMENTATION

The Integrator shall maintain at their facility one full and updated set of all applicable maintenance documentation. In addition, the Integrator shall supply one full set of documentation to be maintained at the Consortium offices and shall update them periodically as needed.

The operation and maintenance documentation will be comprised of the Operation and Maintenance (O&M) manuals, User Manuals and System Administration Manuals.

The O&M documentation shall be submitted prior to OPT testing.

9.6.5.1 O&M Manuals

The O&M manuals shall be a detailed presentation and shall include illustrations where applicable. For each unit, it shall include, but shall not be limited to:

- General description;
- Functional descriptions;
- Functional block diagram;
- Operating instructions;
- Maintenance and repair procedures;
- Test procedures;
- Schematic drawings and circuit diagrams; and
- Parts list;

Each type of maintenance manual shall contain but not be limited to:

- Description of operation including start-up, shut-down and emergency procedures;
- Installation procedures;
• Complete parts identification diagram and list;
• Troubleshooting procedures;
• Inspection procedures;
• Preventive maintenance procedures and program;
• Repair procedures;
• Diagnostic procedures;
• Wiring diagrams;
• Electrical schematics with board and cable identification;
• Adjustment procedures;
• Seasonal maintenance requirements;
• Equipment arrangement and drawings;
• Names and schedules of all lubricants and cleaners used; and
• Other consumable materials for the equipment stating where used, quantity, service intervals, and annual consumption.

A parts list for each equipment item as supplied shall be provided. The parts list shall identify the manufacturer(s) and model/part number.

The manufacturer’s data and handbooks for individual items of the equipment that are a sub-component of the overall system may be used. All such documentation shall be contained in similar binders.

Where an equipment component is of such a nature that local repairs cannot be made and it must be returned to the factory as a unit for overhaul, specific information concerning its repair and breakdown into component parts shall be provided.

9.6.5.2 Equipment Manuals

Equipment manuals for each type of unit shall be provided unless specified otherwise. The manuals shall provide sufficient detailed installation and maintenance instructions to allow for the proper and safe installation, connection and commissioning of the equipment supplied and to operate and maintain the system.

Details of connectors and interconnect cables shall be provided.

9.6.5.3 User Manuals

A User Manual shall be provided for each software application. The User Manual shall include screen captures and easy to follow instructions to assist the users through all of the tasks that they may need to complete. The User Manual shall include an index.

As a minimum, the User Manual shall include all information that is available through the context sensitive help.
Fault procedures shall be described, as well as procedures for dealing with problems.

9.6.5.4 System Administration Manual

A System Administration Manual shall be provided for each software application. The System Administration Manual shall outline all of the configuration parameters, details on how to configure the parameters, back up and recovery process, trouble shooting techniques and technical support information.

Fault procedures shall be described, as well as procedures for dealing with problems.

9.7 Inspections

Per the CDA, the Integrator shall be required to accommodate all oversight and inspection activities by the Independent Engineer, TxDOT, and the Federal Highway Administration and their agents.

9.8 Testing

The Integrator shall perform a schedule of system testing at prescribed stages of development, to demonstrate the successful development of the system and the adherence to the functional requirements.

The testing regime that is outlined below has been developed to provide sequential testing of equipment and software in order to help isolate problems and to make troubleshooting easier. Each set of tests must be completed before the next set of tests is initiated.

9.8.1 FACTORY ACCEPTANCE TESTING

Testing is first completed at the factory in order to ensure that the required functionality of the hardware and software has been met. Testing is completed in a standalone manner for the hardware. Software testing will include the use of simulators or hardware components.

Factory Acceptance Testing shall be performed to ensure that the supplied and developed components meet all functional and environmental requirements and specifications. Factory Acceptance Tests shall be performed prior to onsite installation. For commercial off-the-shelf products, the FAT may be replaced by stamped quality testing documents.

Factory Acceptance Testing (FAT) shall be completed on the software to confirm that the required functionality can be delivered by the software before it leaves the factory environment. For commercial off-the-shelf products, the FAT may be replaced by stamped quality testing documents. The FAT on the software shall confirm, in a controlled environment, that the required functions are delivered. Each requirement listed in the specification shall be tested. The central system software FAT may be completed with field devices or components running in simulation mode or with representative field samples.

9.8.2 PRE-INSTALLATION TEST

The Pre-Installation Test (PIT) is completed once the hardware arrives on site and before it is installed. The PIT confirms that there was no damage during shipping and will include power on and off and device inspection.
9.8.3 PROOF OF PERFORMANCE TESTING

Proof of Performance (POP) Testing shall be completed on each device in the field once it has been installed and configured. The POP shall be completed on the device in isolation to confirm that the installed device meets the required functionality. At a minimum, the installation test for each unit shall include (as applicable): power-up/power-down tests, log-on/log-off tests, verification of major functions, and verification of operational interfaces to other devices.

9.8.4 SUB-SYSTEM INTEGRATION TESTING

The Sub-System Integration Testing (SIT) shall be completed on each subsystem once all of the necessary devices have been installed and POP tested successfully and the communications network tested. The purpose of the SIT is to confirm that the devices are fully integrated with the other devices that they interface or interact with.

9.8.5 SYSTEM ACCEPTANCE TESTING

The SAT is the final test to be completed and can only be initiated once all of the system elements have been installed and configured and all FAT, POP and SIT tests have been successfully completed. The SAT looks at the entire system and tests are completed to ensure that the overall functional requirements are met. The SAT is typically done from the central system software out to each of the devices and is known as an end-to-end test. Where software interfaces with other software, this interface shall be tested through the SAT for each piece of software.

Each requirement listed in the specification shall be tested.

9.8.6 OPERABILITY PERIOD TEST

The Operability Period Test (OPT) is initiated once the SAT has been completed and operation has commenced. Through the OPT, the system is tested under full operations to ensure that the performance requirements are met and to measure the system reliability and availability. System failures will result in the restart of the OPT.

9.9 Training

9.9.1 TRAINING PLAN

Training is a crucial element of the handover of the system to the Operations and Maintenance staff. A training plan will be submitted outlining the course content for each training session, the staff that is expected to attend the training sessions and any training requirements. The training will be conducted over many days and include handouts and manuals. Exercises shall be prepared to allow the trainees to practice what has been taught. The following training will be provided:

- **User training** – Users are any of the administrative personnel, operators, enforcement staff or toll collectors that will use the system to perform their day to day functions. Training shall be provided on all of the system functions, high level troubleshooting, and reporting.

- **System Administration training** – System Administrators include all staff that will be required to perform system backups, archiving, configuration, restarts, and other system related functions. Training shall be provided on day-to-day functions, trouble shooting, emergency system maintenance, and preventative maintenance.
• **Maintenance training** – Maintenance staff include all personnel that will perform preventative and emergency maintenance on the system hardware. Training shall be provided on all preventative and emergency maintenance that may be required.

The Integrator shall provide information, procedures, and instructions the Consortium and their agents on the proper operation and maintenance of the ITS and TCS.

The Integrator shall provide a minimum of four hours of classroom training for up to twelve persons in each of the following categories:

- System Administration Personnel.
- Field Maintenance Personnel.

Classroom training shall reference the operating and maintenance manual, where applicable, and consist of printed materials accompanied by verbal instructions and hands-on training or job shadowing with the applicable equipment or operating environment of the system.

Classroom training shall be completed prior to Service Commencement.

### 9.9.2 MANUALS

Training manuals shall be provided for each training participant, additional copies shall be provided. The manuals shall provide information on all of the topics covered during each of the training sessions and include exercises and screen captures. The Training Manual shall include space for the users to take notes during the training sessions.

The Training Manuals shall be provided at the initiation of each training session.

The Integrator shall prepare and submit an operating and maintenance manual describing all standard operating procedures necessary for the system administration, operations, and maintenance of the system in accordance with the Specifications.

The operating and maintenance manual shall provide an overall description of the function to be performed and include sufficient detail to enable a knowledgeable person with limited related experience and training to perform the necessary functions of the covered material. The operating and maintenance manual may be organized into multiple documents to address separate functional areas.

The system administration portion of the operating and maintenance manual shall include instructions for administering system level functions including, but not limited to, user access and control, password administration, software management, data backup and recovery, dynamic pricing parameters and traffic management parameters.

Such instructions shall provide an overall description of the system administration functions and include sufficient detail to enable a knowledgeable person with related experience and training to perform the necessary functions of the covered material.

The operations portion of the operating and maintenance manual shall include instructions for starting (or restarting), operating, and monitoring the system.
Such instructions shall provide an overall description of the system operations and include sufficient
detail to enable a knowledgeable person with related experience and training to perform the
necessary functions of the covered material.

The maintenance portion of the operating and maintenance manual shall include instructions for the
repair and maintenance of all equipment, servers, and software associated with the system.

9.10 Substantial Completion

Prior to commencement of ITS and toll operations for all segments of the project, the Integrator
shall be required to demonstrate interoperability of the ITS and TCS.

The Interoperability Demonstration shall indicate:

• Compliance with all applicable TxDOT statewide interoperability and compatibility
  standards, requirements and protocols; customer account maintenance, management,
  and reconciliation; and funds transfers among all participants.

• Interoperability with the electronic toll collection system and violation enforcement
  system and protocols utilized or to be utilized on such other highway facilities, to the
  extent such systems and protocols are in common with or substantially similar to
  TxDOT’s.

• NTTA and the Integrator shall conduct demonstration and performance testing of
  interconnection and interoperability of the TCS with NTTA’s CSC Host at least 60 days
  before the projected Service Commencement Date, with a view to identification and
  correction of any problems no later than 30 days before the Service Commencement
  Deadline.

Prior to Commencement of Operations, TxDOT will issue a written certificate of Substantial
Completion at such time as Substantial Completion occurs. In determining whether Substantial
Completion of the ITS and TCS has occurred, the Integrator will be required to demonstrate
satisfaction of the following criteria:

• Whether the permanent ITS and TCS is completed, has passed all demonstration and
  performance testing in accordance with the Project Management Plan, including
  demonstration of interoperability, and is ready for normal operation as defined by the
  Operational Testing Plan.

• Per Section 7.8 of the CDA, the Integrator shall deliver to the Consortium all reports,
  data and documentation relating to such demonstration testing, and such testing shall
  demonstrate that the ITS and TCS meets the minimum threshold performance
  standards and requirements set forth in the Project Management Plan, and the
  minimum interoperability performance standards set forth in the Technical Documents,
  for commencing normal, live use and operation.

After attaining Substantial Completion, the Integrator shall prepare and complete a Punch List of
items to be remedied prior to Service Commencement.
9.11 Acceptance

The Integrator shall ensure that all components of the ITS and TCS meet TxDOT and Consortium requirements for Service Commencement within the constraints of the Project Schedule, to meet the Service Commencement milestone for the Project.

The Integrator shall work with the Consortium and the Independent Engineer to ensure that all conditions and procedures required by the CDA are satisfied; including cooperation with Independent Engineer inspections of the ITS and TCS.

The Integrator shall immediately act to remedy any ITS and TCS issues identified by the Consortium, the Independent Engineer, or TxDOT that impede the attainment of the Service Commencement milestone.

The Consortium and Independent Engineer shall have the right to identify any Punch List items whose resolution is critical to achieving Service Commencement. If any of these critical items are found to be the sole reason for, or substantial contributor to, delay of Service Commencement, the Consortium shall have the right to pursue compensation from the Integrator for the loss of revenue caused by such delay.

Promptly after achieving Service Commencement for a Segment or Operational Section, the Integrator shall perform all remaining work, including completion of all Punch List items.

The Integrator shall provide the Consortium with written notification upon determining that the ITS and TCS is ready for Final Acceptance. This shall include completion of all Punch List items and satisfactory completion of Operational Testing.

During the fifteen-day period following receipt of such notification, the Integrator shall accommodate inspection by the Independent Engineer of all Punch List items, a review of the As-Built plan sets, test results, and such other investigation as may be necessary to evaluate whether the conditions to Final Acceptance are satisfied.

9.12 Handoff

Prior to the conclusion of the Integrator’s services under its contract with the Consortium, the Integrator shall prepare a Transition Plan detailing the procedures and requirements necessary to successfully transfer all aspects of the system operation and maintenance to the Consortium as appropriate.

10. OPERATIONS

Towards the end of deployment, the Consortium will be required to provided for the on-going operations and maintenance (O&M) of the toll, ITS, tunnel and communication systems, and hardware. This section discusses a recommended approach.

Four main functional areas will need to be supported by the O&M organization:

- Management: Core team of a manager and financial analyst to ensure the proper supervision of the program and provide fiscal oversight.
- Toll Operations: Unlike most toll facilities, almost all of the customer service work will be done by NTTA. But because NTTA will charge for each Video Transaction
transmitted to them, it is prudent to review these images for quality and readability. The toll operations staff would provide this function. Over the life of the concession, the number of vehicles without automatic vehicle technology devices will grow to almost all vehicles and significantly reducing the number of images to be reviewed.

The addition of HOV enforcement will require a sizable interaction with local law enforcement and court officials to facilitate effective enforcement. Staff resources will be need to support this effort.

- Central Systems Maintenance: The daily routines of updating, backups, trouble shooting, network maintenance, and system administration will require a group of systems professionals to keep the various systems operational. These daily functions can be handled by in-house staff. However, on-going modifications to installed systems are generally best handled by the developers of the original system.

- Field Systems Maintenance: Following the approach noted previously, and given the performance requirements placed on the Consortium, a 24/7 field equipment maintenance service will be required.

- Highway Operations: One of the performance requirements requires that the managed lane operate at 50 mph unless there is a planned event or incident that causes a reduction in speed. To avoid potential financial penalties, operational staff will be required to monitor traffic conditions on a 24/7 basis.

The operational cost estimate will be based on the use of in-house resources to provide a baseline for these services that could be potentially provided by a contractor.

11. MAINTENANCE PLAN

An integrated solution approach to the maintenance of the systems will be pursued, as all systems (Toll Collection Systems and ITS) will be considered part of the whole Managed Lane project system, sharing communications and control center facilities. The skill sets (communications, electronics, IT) required for maintaining each of these systems is seen as similar across each type of system. Maintenance staffing will therefore be cross-trained and responsible for all aspects of each system, including: maintenance of central systems; field equipment; and communications.

The Maintenance Program will include the following types of maintenance:

- **Responsive Maintenance:** The repair or replacement of failed equipment and its restoration to safe, normal operation. Typically unscheduled, it is in response to an unexpected failure or damage.

- **Preventive Maintenance:** Also called "routine" maintenance, it is the activity performed at regularly scheduled intervals for the upkeep of equipment. This activity includes checking, testing and inspecting, recordkeeping, cleaning, and periodic replacement when called for in the preventive maintenance schedule.

- **Emergency Maintenance:** Emergency maintenance is similar to responsive maintenance in that it is initiated by a fault or trouble report. However, in this case, the fault is more serious and requires immediate action. Events such as knockdowns, spills, exposed electrical wires, road blockages, etc. are examples of event reports that may require emergency maintenance. Of course, there can also be operational...
emergencies — e.g., stuck barriers on dedicated HOV lanes or failed lane control signs — that need to be dealt with quickly in order to minimize hazardous circumstances.

Maintenance equipment, special trucks, and spare parts will be procured to provide sufficient system support during the construction process.

11.1 Requirements

The following shall be the elements included in the Maintenance Scope of Work.

- Roadside System Hardware and Software
- Communications Network
- Central System Hardware
- Central System Software

The Integrator shall develop a detailed Maintenance Management Plan that covers all aspects of the maintenance operations and services to be provided. The Maintenance Management Plan shall include the following information:

- Maintenance Service manuals;
- List of Spare Parts;
- Inventory Control Plan:
- Maintenance Management Information System functionality:
- Software Maintenance;
- Special Tools and Equipment:
- Failure Tracking and Corrective Actions;
- Maintenance Reliability Analysis; and
- Vendors for equipment maintenance services

The Integrator shall provide twenty-four hours a day, seven days a week (24/7) on-call coverage for all maintenance related activities. Response times and performance requirements must satisfy the CDA requirements.

11.2 Vehicles and Equipment

The following vehicles and equipment will be required, as a minimum, to maintain the systems:

- Bucket truck to service DMS, CCTV cameras, Vehicle detection, etc;
- Service vehicles;
• Crash attenuator truck;

• Cellular telephones equipped with walkie-talkie functionality to provide communications to field staff;

• Lane closure equipment (cones, signs etc); and

• Laptop computer with toll system controller, ITS device, and network management software and troubleshooting tools.

• Suite of tools and measurement devices required for the maintenance and testing of roadside, communications and computer hardware and equipment.

A technical workbench and workroom equipped with specialized equipment will also be necessary to repair field equipment and should be located in the Maintenance Building. An indoor storage area for the spare equipment provided with the system.

The Integrator shall provide all vehicles, test equipment, tools, PDAs, pagers, computers, and any other items required for the maintenance staff to perform their maintenance activities. All required test equipment and tools shall be on-site and in adequate supply, with all required personnel trained on their use.

All test equipment shall be standard units that are capable of achieving the measurement they are intended to make.

11.3 Spare Parts Inventory

The Integrator shall purchase and maintain the spare parts and consumables inventory. The Spare Parts List shall be included in the Maintenance Plan.

The list of the spare parts that would be required at the opening of the facility is provided in the Costs and Quantity Tables. As experienced is gained in the maintenance of the systems, the inventory would be adjusted accordingly. It will be important to monitor the lead times and delivery schedule for certain items to make sure that spares are available in a timely fashion. Focus would be on the toll system to ensure the continued collection of revenue.

The Integrator shall be responsible for monitoring the inventory quantity and ensuring that the inventory is maintained to the required levels.

Prior to the scheduled date for Service Commencement, the Integrator shall have purchased and have on hand the approved inventory of spare parts. The spare parts shall be purchased on behalf of the Consortium.

11.4 Staffing

The existing ITS elements must be maintained throughout the construction process; therefore, a couple qualified technicians will be hired once construction begins to maintain this equipment. As new system elements from the ITS, Toll Collection, and Tunnel Systems are accepted from the applicable contractors and system integrator, additional staff will be hired.

The maintenance staff that is hired before the completion of the construction process will provide construction support during the system installation stage, working alongside the contractor and
getting training on site. These hired maintenance personnel will not only obtain hands-on experience, but serve as the maintenance support staff for sections of the systems that are turned over by the system integrator before the construction process is complete.

The maintenance staff will grow to the eventual planned size by the end of the construction process, with additional staff brought on as more sections of the systems are completed.

This approach of bringing on in-house maintenance personnel during the construction process instead of requiring the contractor to provide maintenance support will be overall more cost effective as it will provide support needs during the construction process, and lead to a well qualified and experienced staff once the systems are fully operational at the end of the construction process.

A maintenance team must be available 24 hours a day, 7 days a week to support the Toll, ITS and communications system. Team members should be cross-trained to provide support to be able to meet all of the maintenance requirements. The maintenance team will require a workroom for repairs and storage of maintenance equipment. Maintenance staff will also be required to perform routine maintenance during off-peak hours.

Staffing will consist of two full-time crews with regular work hours covering the peak traffic periods. Crew technicians will also provide on-call support on an overtime basis to cover emergency maintenance needs during non-peak periods 24 hours/7 days a week.

The necessary staff to follow the maintenance procedures outlined by the system supplier will be required. The following summarizes the anticipated staff positions and the quantity of each position that is expected.

- **Maintenance Supervisor:** This position is responsible for supervising the overall maintenance activities for all three systems components.

- **System Administrator/System Analyst:** This position is responsible for maintaining the central software/hardware and LAN or WAN. System backups, archiving, O/S upgrades, patches, and other network management tasks will be the responsibility of the System Administrator. Configuration of the Toll and ITS software will also be undertaken. Experience with Windows O/S, networks and databases will be crucial.

- **Maintenance Technician:** The Maintenance Technician will be responsible for trouble shooting, completing emergency maintenance, and undertaking preventative maintenance. They will also need to undertake system repairs such as fiber splicing and minor equipment repairs. Electronic technologists or electronic technicians are suggested. There should also be shift leaders who are more senior so that junior inexperienced staff could be supervised and trained on the job by the senior staff.
APPENDIX A

DESIGN SCHEMATICS