Attachment 2
US-74 Express Lanes ConOps Final Rev

U-5526A - US 74 Express Lanes

Concept of Design & Operations

North Carolina Turnpike Authority

January 12, 2016

ATKINS

Plan Design Enable

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1. Introduction

1.1. Document Purpose and Project Overview

With the US 74 Express Lanes project, the North Carolina Department of Transportation (NCDOT) proposes to convert the bus lanes in the median of Independence Boulevard (US 74) in Charlotte from I-277 to Wallace Lane to Express Lanes. This conversion will include the bus lanes that currently exist between I-277 and Albemarle Road (NC 27), as well as the bus lanes that are currently being constructed from Albemarle Road to Wallace Lane.

The purpose of this project is to provide travel time reliability in the Independence Boulevard corridor. In combination with other improvements proposed on Independence Boulevard (U-2509) to the east in Matthews, the proposed project will give motorists the choice of paying a fee for a reliable trip time on US 74 between I-277 in Charlotte and I-485 in Matthews. The project has the potential of opening the first Express Lanes in the state to the motoring public.

NCDOT's Project Development and Environmental Analysis (PDEA) Branch staff will be guided thru the environmental document process by another engineering firm (TGS Engineers). It is NCTA's intent to develop a plan for toll technology, civil infrastructure and ITS that provides the detail necessary for the completion of the PDEA effort as well as providing other stakeholders with key information toward their respective areas of interest. In the fall of 2014, NCTA completed a series of plans (included in this report as **Appendix A**) that detail the ITS, signing, toll site and gate control systems, at a conceptual level. This report is a logical continuation of that effort.

Important Note: The work leading to this current report builds off the previous work and research contained in an earlier report prepared by AECOM for NCTA entitled "US 74 Managed Lanes Concept of Operations," dated January 13, 2014. Every effort has been made to eliminate any duplication of work between the earlier and the current documents.

The ultimate goal of this report is to bridge the knowledge gap between the AECOM report and the inception of:

- final design requirements for civil, intelligent transportation system (ITS), signing and gate control, and
- requirements for the toll system procurement

This report provides a detailed description of the concept for the roadside toll collection system (RTCS) and back office system (BOS), including daily traffic management, maintenance, and tolling activities. The report will also include further development of the ITS and the communication plan for ITS data. Lastly, the report will discuss operational plans and reporting requirements.

1.2. Acronyms

AET – All-Electronic Tolling
AID - Automated Incident Detection
ALPR - Automated License Plate Recognition
AVI - Automated Vehicle Identification
AVC – Automated Vehicle Classification
BIS – Business Intelligence System
BOS - Back Office System
CAMS - Customer Account Management System
CARAT – Congestion Avoidance and Reduction for Automobiles and Trucks
CATS - Charlotte Area Transit System
CCTV – Closed-Circuit Television
CDOT – Charlotte Department of Transportation

CFD - Charlotte Fire Department
CMPD - Charlotte-Mecklenburg Police Department
CRM – Customer Relationship Management
CSR – Customer Service Representative
CSC – Customer Service Center (NCTA)
CRTPO - Charlotte Regional Transportation Planning Organization
CTI – Computer Telephony Interface
DDD – Detailed Design Document
DIMS - Device Inventory Management System
DMS - Dynamic Message Sign
DTS – Dynamic Tolling Software
DVAS – Digital Video Auditing System
FHWA – Federal Highway Administration
FPMS- Financial Processing Management System
GCS – Gate Control System
GIS - Geographic Information System
GL – General Ledger
GP – General Purpose
ICD – Interface Control Document
IMAP – Incident Management Assistance Patrol
ITS - Intelligent Transportation System
IVR - Interactive Voice Response
KPI – Key Performance Indicators
LD – Liquidated Damages
LOS – Level of Service
MOMS – Maintenance Online Management System
MOU – Memorandum (or Memoranda) of Understanding
MRP – Maintenance Rating Program
MRTMC – (NCDOT) Metrolina Regional Transportation Management Center
MUTCD – Manual of Uniform Traffic Control Devices
MVD - Microwave (Radar) Vehicle Detector
NCDOT - North Carolina Department of Transportation
NSF – Insufficient Funds
OCR – Optical Character Recognition
OD - Origination and Destination
ORT - Open Road Tolling
PCI – Payment Card Industry
PDEA – Project Development and Environmental Analysis
QOS – Quality of Service
ROCS – Roadway Overview Cameras System (part of Toll Collection System)
RTCS - Roadside Toll Collection System
SAMS – System Administration Management System
SHP – State Highway Patrol
SOP – Standard Operating Procedure
STI - Strategic Transportation Investment
STIP - State Transportation Improvement Plan
STOC – State Transportation Operations Center
TCS - Toll Collection System
TDM – Time-Division Multiplexing protocol (formerly IAG (Inter-Agency Group) protocol
TIMS - Traffic Incident Management System
TMC – Transportation Management Center
TMS – Traffic Management System
TOC - Traffic Operations Center
TPMS – Transaction Processing Management System
TSI – Toll System Integrator
UPS – Uninterruptable Power Supply
VECTOR - Violation Enforcement Customer Service Toll Operations Reporting

1.3. Project Principles

This US 74 Express Lanes Concept of Design and Operations Report will describe concepts and solutions that:

- Are intended to fit into a consistent regional framework of tolled and actively managed transportation facilities including the developing regional network of Express Lanes facilities
- Support all potential tolling schemes, particularly congestion pricing
- Have toll site designs that address factors including ongoing roadway design work, limited ROW, an urban environment, a reversible lane segment, traffic control gates and other unique project features
- Propose a toll collection system that is consistent with, but expands upon, current NCTA tolling practices. This includes:
    - The Roadside Toll Collection System (RTCS) which is the tolling hardware installed at the roadside
        - A subset of the RTCS is the Electronic Toll Collection System (ETCS), which is the technology that reads vehicle transponders
    - The Toll Facility Infrastructure – the civil elements (gantries, buildings, etc.) that support the RTCS
    - The Back Office System (BOS), which is the processing and invoicing back-end for the toll collection system.
- Feature logically integrated communications with the Metrolina Regional Transportation Management Center (MRTMC) in Charlotte and State Transportation Operations Center (STOC) and NCTA Customer Service Center (CSC) in Raleigh
- Feature state-of-the-art ITS technology
- Support local transit programs
- Feature state-of-the-art customer guidance and traveller information

1.4. Coordination with Other Projects

Multiple toll projects are either currently under construction or in the planning stages in the Charlotte metropolitan area. These projects include “greenfield” conventional toll road projects and Express Lanes projects, and projects with unique delivery mechanisms, such a public-private partnerships. In terms of the “big picture” context, it is necessary that all these tolling projects form a consistent, coordinated transportation system, so that the motoring public does not perceive a complex collection of disparate toll projects close together that are difficult to navigate and use. Decisions made on the U-5526 project regarding toll collection and operations will impact similar elements of these other toll projects.

The projects are listed below roughly in order of how advanced they are in the project development cycle (from most advanced to least).

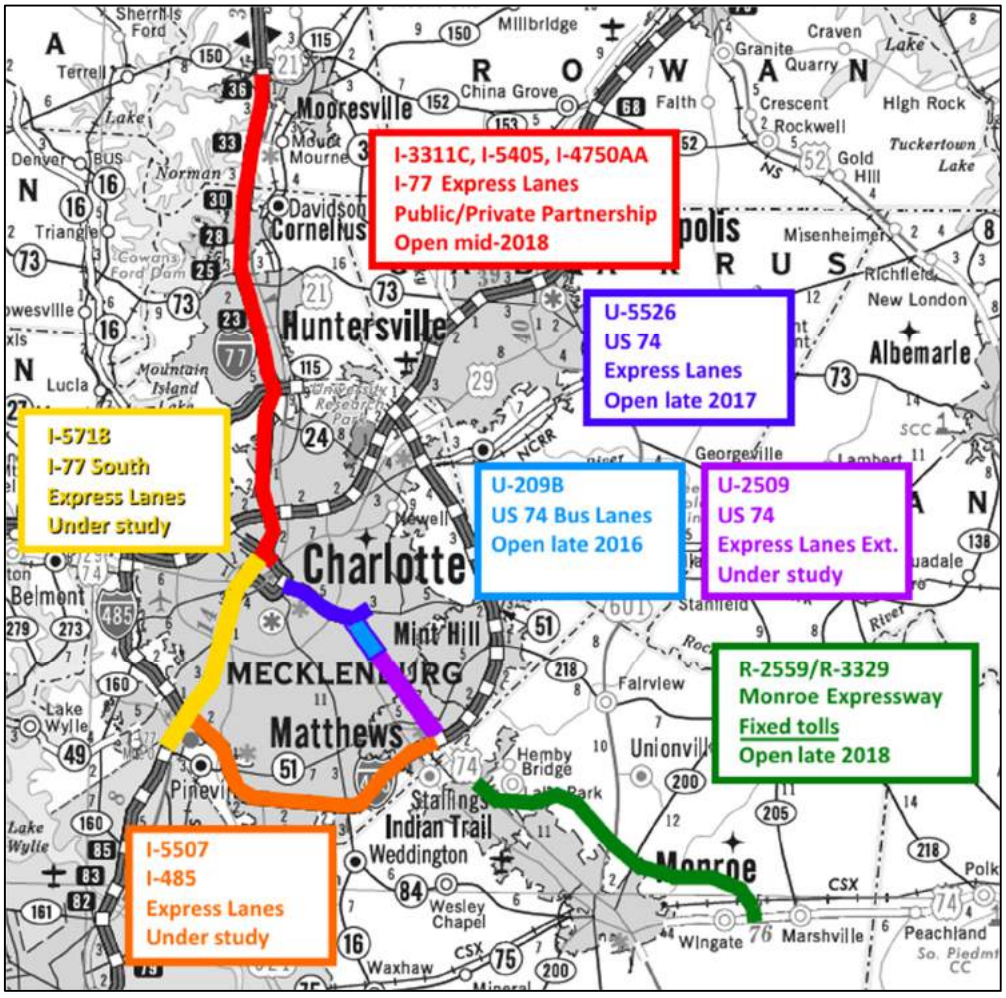
- US 74 Bus Lanes (NCDOT Project U-209B)
- Monroe Expressway (R-2559/R-3329)
- I-77 Express Lanes (I-3311C, I-5405, I-4750AA)
- US 74 Express Lanes (U-5526)
- US 74 Intelligent Transportation System (ITS) (U-209BA)
- I-485 Express Lanes (I-5507)
- US 74 Express Lanes Extension (U-2509)
- CATS Hawthorne Bridge Replacement (City of Charlotte)
- I-77 Express Lanes South (I-5718)

Most of the projects below are shown in **Figure 1**.

The exceptions are:

- Hawthorne Bridge Replacement. This location can be best seen in **Appendix A**, Sheet 4.
- U-209BA ITS – This project coincides with U-209B project limits.

Figure 1. Area Toll-Related Projects of Interest



1.4.1. US 74 Bus Lanes (NCDOT Project U-209B)

Project U-209B is a NCDOT construction project that will extend the existing bus lanes (now ending at Albemarle Road) east to Wallace Lane. This project will provide most (but not all) of the civil infrastructure that will eventually become part of the first phase of the US 74 Express Lanes project. This project is scheduled to be complete in late 2016. Under ideal circumstances, the opening of the US 74 Express Lanes would coincide with the schedule completion of U-209B.

1.4.2. Monroe Expressway (R-2559/R-3329)

The Monroe Expressway, a 21-mile fixed toll facility bypassing downtown Monroe on the north side, has been delayed due to issues related to the environmental process. However, environmental permits were received on May 8, 2015, and the project has received an Unlimited Notice to Proceed. Construction may be completed as early as November of 2018. The westernmost terminus of the project is approximately six miles from the easternmost terminus of the US 74 Express Lanes project. The primary area of coordination would be signing consistency; once the Express Lanes are extended to I-485, the two projects will essentially be connected.

1.4.3. I-77 Express Lanes (I-3311C, I-5405, I-4750AA)

The I-77 Express Lanes project is a 26-mile long corridor between I-277 (Brookshire Freeway) in Charlotte and Exit 36 in Mooresville. This project is a public-private partnership (P3), with Cintra being awarded the concession agreement in April of 2014 for the project. The project has reached Financial Close. The project could be open to the public as early as mid-2018. The southeast end of the project, west of the Tryon Road interchange with I-277, is less than 1.2 miles west from the western end of the US 74 project. The primary areas of coordination would be signing consistency, traffic management/coordination and dynamic tolling pricing policies.

1.4.4. US 74 Express Lanes (U-5526)

This project is the subject of this report. Project U-5526 consists of two primary segments:

- The western half: bus lanes constructed under NCDOT project U-209F, and
- The eastern half: project U-209B, which eliminated at-grade intersections and constructed a dedicated median bus lane in each direction, tying into the U-209F section at Albemarle Road.

The civil, tolling, signing and ITS upgrades needed to turn the integrated bus lanes into Express Lanes will be included in U-5526. The project corridor is approximately 5.8 miles long. U-5526 is planned to be complete in late 2017.

1.4.5. US 74 Intelligent Transportation System (U-209BA)

This project, original scheduled for letting in FY 2016, was to provide ITS devices (five closed-circuit television (CCTV) cameras), fiber-optic cabling (installed in existing conduit), and associated equipment to installed concurrent with project U-209B. Since the US 74 Express Lanes project would require a similar (but expanded) scope of work, NCDOT Division 10 has decided to fold the U-209BA project into the U-5526A Express Lanes network.

1.4.6. I-485 Express Lanes (I-5507)

A large Express Lane project of over 18 miles in length is under study by NCDOT on I-485 south of Charlotte. The study area stretches from I-77 on the west end to US 74 on the east end. The primary areas of coordination would be signing consistency, toll site standards and practices, dynamic tolling pricing policies and practices, and toll collection methods.

1.4.7. US 74 Express Lanes Extension (U-2509)

U-2509 is an extension of the U-209B project to the east to connect with I-485. The toll system described herein will be operational when the U-2509 project extends the Express Lanes system. The timeline for this extension is not known, but is not likely before 2019. The existing toll gantries, gate system and related equipment will have to be replaced by the construction needed for either the “1-lane in each direction” or the “2-lanes in each direction” alternative. Additional ingress and egress points will require additional toll zones as per the final design of U-2509. Additional ingress and egress points will also affect the signing plan. The ITS Concept will not however be substantially affected, although new devices will need to be added.

1.4.8. CATS Hawthorne Bridge Replacement

The City of Charlotte is in the process of replacing the subject bridge, located on the west end of the US 74 Express Lanes, as a part of the LYNX Gold Line Phase 2 project. The bridge replacement is anticipated to occur in 2016/2017 pending funding. See Section 3.3 for possible impacts of this project.

1.4.9. I-77 Express Lanes South (I-5718)

This project would add approximately 10 miles to the network of Express Lanes on I-77, from I-277 to I-485 south of Charlotte. The project is included in the 2016-2025 State Transportation Improvement Plan (STIP) but studies haven't begun due to the legislative cap on toll projects NCDOT is allowed to study. Environmental studies and project preliminary designs may begin in fall 2015. No coordination specific to this project is projected at this time.

1.5. Project Recommendations

Embedded in the body of text of the report are action items for NCTA/NCDOT, highlighted by their placement in a grey text box, like this:

Specific action item

1.6. Planned Future Revisions of this Document

The US 74 project will be built in two phases. While this document covers the first segment (from I-277 to Wallace Lane), it is recognized that facility extension from Wallace Lane east to I-485 (Phase II, project U-2509) is likely to occur in the near future. Therefore, it is envisioned that this Concept of Design and Operations will need to be updated in advance of the completion of the environmental document for the extension of the US 74 Express Lanes east to I-485.

1.7. Referenced Documents

FHWA Price Managed Lanes Guide, dated October 2012.

NCDOT Intelligent Transportation System Configuration Management Plan, dated July 2, 2015.

NCTA All-Electronic Tolling Standard Drawings, dated October 7, 2014

NCTA Toll Collection System Detailed Design Document, Roadside Toll Collection System, by XEROX, dated November 4, 2010

NCTA Toll Collection System Detailed Design Document, Back Office System, by XEROX, dated February 6, 2015

NCTA Toll Collection System General System Detail Design, v1.8, Back Office System, by XEROX, dated March 31, 2015

NCTA Traffic Management Center Standard Operating Procedures, dated July 10, 2014

North Carolina Statewide Intelligent Transportation System Strategic Deployment Plan - Metrolina Regional Report, by Kimley-Horn & Associates, undated.

US 74 Managed Lanes Concept of Operations, by AECOM, dated January 31, 2014

US 74 Managed Lanes Final Level 1 Traffic and Revenue Study, by Stantec, dated June 11, 2015

2. EXISTING CONDITIONS

Current conditions on US 74 in the project area are described in the following sections.

2.1. Bus Lane Operation

According to the AECOM report, "When an initial phase of Project U-209 was completed in 1998, the HOV facility was opened as a two-way transitway for use only by Charlotte Area Transit System (CATS) express buses traveling along US 74. Currently, the transit agency operates 33 inbound bus trips between 6 AM and 9 AM and 33 outbound bus trips between 4 PM and 7 PM along the transit way each weekday."

2.2. Law Enforcement Patrols

Charlotte Metropolitan Police Department (CMPD) provides primary traffic enforcement on Independence Boulevard (US 74) and I-277. Due to the restricted access, speed enforcement is the most common activity. The State Highway Patrol (SHP) also has the ability to conduct traffic stops and enforcement. CMPD and SHP have a formal agreement that I-277 is enforced by the CMPD.

2.3. ITS Infrastructure & Operations

2.3.1. TMC Operations & Safety Patrols

2.3.1.1. Metrolina Regional Transportation Management Center

NCDOT's Metrolina Regional Transportation Management Center (MRTMC) is located at 2327 Tipton Drive, Charlotte (near the I-77/I-85 interchange). The MRTMC operates the ITS devices on the most of the controlled access highways in the region. All of the ITS devices operated and maintained by NCDOT are controlled by software installed at the MRTMC. Since NCDOT ITS software is not available statewide, the STOC in Raleigh cannot control ITS devices located in Charlotte.

The MRTMC provides still CCTV images to NCDOT's travel information website. The software captures images at regular intervals and uploads them to an FTP site for posting on NCDOT's travel information website.

2.3.1.2. CDOT Transportation Management Center

The Charlotte Department of Transportation (CDOT) Traffic Management Center (TMC) is presently located in the old City Hall on East Trade Street, but is planning to relocate to the City's new Joint Communication Center at the intersection of North Graham Street and Statesville Avenue in 2018. The current facility will be used as a back-up from that point forward.

The MRTMC and the CDOT TMC can share control and viewing of their CCTVs. The MRTMC-controlled cameras are mostly analog, but newer installations are equipped with video encoders. CDOT's CCTV network is all digital and includes a different CCTV control software from that used by NCDOT. The shared CCTV system does not permit pan-tilt-zoom control of the CCTV from any locations other than the MRTMC and the CDOT TMC.

2.3.1.3. Incident Management Assistance Patrols

Regional Incident Management Assistance Patrols (IMAP) are conducted out of the MRTMC facility. The MRTMC provides incident management and service patrols on I-77 (three routes, two shifts), but does not patrol either US 74 or I-485. Since May of 2015, the IMAP program has been sponsored by (and partially funded by) State Farm Insurance, and re-branded "NCDOT State Farm Safety Patrol". Operational control and staffing remains an NCDOT responsibility.

2.3.2. ITS Devices Operations & Maintenance

The US 74 corridor currently contains a mix of older legacy ITS infrastructure and newly upgraded devices.

2.3.2.1. Closed-Circuit Television Cameras

Currently, there are nine CCTV cameras along US 74 between I-277 and Farmingdale Drive and one CCTV camera along Albemarle Road (shown in **BLUE** on the ITS Concept). These cameras are owned by NCDOT. CDOT has assumed maintenance responsibility and converted these analog cameras to digital video equipment (with an Ethernet edge switch and encoder) and now CDOT operates the cameras on their traffic management network. NCDOT reimburses the City for maintenance through the Schedule C and D rates. CDOT shares control of their cameras with NCDOT, CMPD and the Charlotte Fire Department (CFD). CMPD and CFD have priority usage during incidents. Therefore, the cameras on US 74 cannot be considered as dedicated to traffic surveillance and traffic management to the degree needed to operate the Express Lanes.

2.3.2.2. Dynamic Message Signs

There are two existing monochrome dynamic message signs (DMSs) on the project used solely for NCDOT incident management purposes, shown in **BLUE** on the ITS Concept in **Appendix A**. The DMS on US 74 was recently relocated to near Wallace Lane and is connected to the MRTMC by dial-up telephone communications. The DMS on Albemarle Road is on the fiber-optic trunk cable discussed below. NCDOT maintains these two DMS.

2.3.2.3. Detection

Currently, there are five pairs of NCDOT passive microwave (radar) vehicle detectors (MVDs) along US 74 between I-277 and Farmingdale Drive, and one pair along Albemarle Road, that were installed in Project U-209F. The existing detectors are not uniformly spaced, the spacing varies from 0.43 to 1.4 miles apart, and they are approximately eight years old. NCDOT no longer uses or maintains these detectors.

2.3.2.4. Fiber-optic Cable

CDOT maintains the fiber-optic trunk cable along US 74.

2.3.3. Network Communications with NCDOT TMC and Charlotte TMC

2.3.3.1. Communications between MRTMC and Project Corridor

Currently, a 72-strand single-mode fiber-optic cable with four 1.25" ducts runs from the MRTMC along I-77, Brookshire Freeway, onto US 74, and then to Albemarle Road. The cable along the Brookshire Freeway is spliced in a cabinet-mounted patch panel at 11th and Davidson Streets to a CDOT cable that terminates at the CDOT TMC. NCDOT has allocated 24 strands of this cable for the City's use. The active strands along US 74 are jumpered through to the MRTMC. This cable connects the CCTV cameras to the CDOT TMC and the DMS on Albemarle Road to the MRTMC. Each camera cabinet is connected with six-strand fiber-optic drop cables to the US 74 fiber-optic trunk cable.

2.3.3.2. Project Corridor Communications

With the completion of the U-209B project, which will install four 1.5” ducts from Albemarle Road east to Sharon Forest Drive, there will be four conduits along the US 74 Express Lanes project corridor to be shared between NCDOT and NCTA. The NCTA conduits will be dedicated for use by the Express Lanes project. The ITS Concept (see sheets 4 thru 6) reflects the conduit network at the completion of the U-209B improvements. The existing and proposed conduit network includes pull boxes for future device connections. Wireless communications are proposed to be used to connect to DMS and cameras east of Sharon Forest Drive.

2.3.3.3. Interconnect between Charlotte and Raleigh

Currently there is a not a complete fiber-optic cable connection from the MRTMC to the STOC. Several TIP projects will include fiber-optic cable that will expand the network towards completion. These projects include I-3803B, I-3802A and I-3802B.

Upon completion of those projects over the next three years, there still will be an unfunded gap in the fiber-optic network from the MRTMC to the Triad Regional Transportation Management Center in Greensboro that would in turn could provide the connection to the STOC. The remaining unfunded gap along I-85 is from the I-85 Business/US 29 interchange to the I-73 interchange. Between Greensboro and the STOC there is another gap of 13 miles between I-85/40/Trollingwood-Hawfields Rd. (Exit 152) and Old NC 86 at I-40 (Exit 261). Based upon similar projects, the cost of the missing sections is estimated at over $3M.

2.4. Roadway Maintenance

NCDOT Division 10 maintains the roadway infrastructure, signing and pavement markings along US 74 and Albemarle Road (NC 24).

3. PROJECT NEEDS & REQUIREMENTS

Most project needs and requirements can be divided into two key areas: technological needs and operational needs. These two categories are, by nature, closely related. Those two areas, plus other project needs that follow, are discussed in this section.

3.1. Technological Needs

The technical requirements and needs of the TCS and the ITS were discussed in Section IV.B of the AECOM report. Below are some highlights and expanded details.

3.1.1. Roadside Toll Collection System

The RTCS Contractor shall provide a complete, functioning, state-of-the-art all-electronic toll system utilizing Electronic Toll Collection (ETC) and video processing for identification of vehicles for every toll zone on the toll road.

The toll collection system runs in near-real-time but must have the capability to batch/store transactions locally in the event that a remote facility relegated to leased lines experiences low speed communications.

The RTCS will build a uniform-formatted transaction message (one meeting the requirements of the Interface Control Document, "ICD") at the initial US 74 tolling point whether ETC-based or a video-based transaction.

The RTCS contractor will need to provide the communication and network connectivity between:

- In-lane equipment and the roadside lane electronics
- Roadside lane electronics and the Toll Zone Plaza
- Toll Zone Plaza and the Other contractors are anticipated to provide the civil infrastructure depending on the site conditions and locations of the toll points; the RTCS contractor will connect and test the toll system network connections between all locations including the CSC

The RTCS has the following specific technical needs:

- Automatic license plate recognition (ALPR) with optical character recognition (OCR) capabilities
- Ability to collect discrete transactions without inadvertently grouping multiple vehicles into a single entity
- Vehicle classification system (by axle)
- GPS-based time stamp for transactions
- Online maintenance monitoring system to generate reports and alerts when errors occur
- Site security CCTV camera with pan-tilt-zoom capability
- Fixed toll lane audit camera
- Fixed CCTV camera to monitor and confirm toll rates to RTCS

3.1.2. Electronic Toll Collection Systems

The ETCS has the following technical needs:

- RFID communication between the vehicle-mounted transponder and the ETC antenna
- RFID interoperability/compatibility with Triangle Expressway
- FCC license for RFID communications for the project site
- Capability to read declarable transponders that would be used statewide for all Express Lanes

3.1.3. Back Office System

The BOS has the following technical needs:

- Revenue and fees are allocated correctly to projects
- Facility identification works for all BOS functionalities

- New storefront link to the CSC
- Customer Service Representatives (CSRs) access to customer accounts
- CSR ability to retrieve transactions
- Modifications to the Interactive Voice Response (IVR) tree

3.1.4. Dynamic Tolling Pricing Software

The dynamic tolling software system has the following technical needs:

- Housed in a secure location
- Scalable to adequately serve a future larger Express Lanes system
- Universal transaction messaging system for all statewide systems to communicate to the CSC for use in future procurements
- Standardized ICD that is applicable to the existing BOS System (future implementations of Express Lanes would use this to communicate to the BOS)
- Detailed calculation methodology for the computational methods for the vehicle pricing and scalability to future projects. (Include multiple methods for calculations)
- Capability for the transmission of transactions and trip messages utilizing the universal messaging format that are accepted by the BOS at the CSC (well-documented message that can be applied to the BOS and other future systems that can be procured for future Express Lane projects)
- Research capability at the Host level for the CSRs to audit transactions / trips for customer queries
- Automatic backup at CSC of transactions, images and other such needed data in the corridor to adhere to the data retainage policy

3.1.5. Gate Control System

The gate control system has the following technical needs:

- Proven and dependable technology
- Ease of installation in or on standard concrete median barriers, with a minimal extra expense to customize
- Capable of remote and manual control
- High-visibility gate arms for night-time and inclement weather conditions
- Communications and control software for operations
- Back-up power to mitigate short-term power outages
- Signing to alert wrong-way drivers

3.1.6. Traffic Management & ITS

3.1.6.1. CCTV Cameras

Roadside surveillance via the CCTV system will be used to monitor traffic conditions along the Express and general purpose (GP) lanes of US 74. The CCTV system will also be used to monitor the gate operations to ensure the reversible lanes are cleared before changing direction and that all gates are in correct position. There must be full CCTV coverage along the Express Lane system, including shoulders. The CCTVs used to monitor the US 74 Express Lanes must be dedicated to traffic management purposes. The CCTVs shall have full pan-tilt-zoom control capability from the facility managing the traffic.

3.1.6.2. Vehicle Detection

Vehicle detection via MVDs must provide traffic speed, volume, and density data to both the ITS system and the Express Lane dynamic tolling system. The ITS system uses the data to identify developing traffic conditions for further investigation. The dynamic tolling system utilizes the same data in the pricing algorithms and to ensure compliance with the required performance measures. The congestion measurement algorithms of the dynamic tolling system require MVDs spaced approximately 1/3 mile apart. The MVDs must collect the data by direction and by lane.

3.1.6.3. Dynamic Message Signs (for Traffic Management)

DMS signs will provide incident and traveller information on both the general purpose and Express Lanes along US 74. Additional DMS should be located on the approach to the project so traffic can be diverted from general purpose lanes before entering the Express Lanes. DMS to support tolling are discussed in Section 3.1.8.

3.1.7. Communications Network

The ITS communications network must support the ITS system, the Express Lane tolling operations, and the CDOT operations of the general purpose lanes. The communications system will have to connect:

- Express Lanes CCTV, MVDs and DMS to the TMC that will manage them
- Non-Express CCTV to the CDOT TMC
- Non-Express DMS to the TMC that will manage them

Planning and execution for center-to-center communications links and networks between multiple TMCs and between TMCs and the CSC should comply with NCDOT Information Technology (IT) and Enterprise Project Management Office (EPMO) guidelines.

3.1.8. Signing

Signing for the US 74 Express Lanes is important to maintain safe and efficient traffic operations and to communicate toll rates. At entry points to the US 74 Express Lanes, clear and concise signage is needed in advance of the decision point to explain the following:

- Open/closed status
- Applicable toll rate(s)
- Toll exempt vehicles (e.g. “HOV-3+”)
- Payment methods
- Interoperability with other tolling agencies
- Prohibited vehicles (e.g., “No Trucks”)
- Other business policies (to be determined)

Once on the US 74 Express Lanes facility, motorists must be informed about the egress points in an effective, simple, and clear way. This includes standard NCDOT destination signage both on and in advance of the route.

The overall signing should blend in seamlessly with the existing signage while accomplishing all the goals related unique to the US 74 Express Lanes effort; however, the corridor’s existing static sign plan will be largely unaffected by the project.

The signing concept plan for the project has been developed by NCTA; see **Appendix A**, sheets 1 through 3.

3.2. Operational Needs

3.2.1. Express Lane Operations

From an operational perspective, there are three primary subsystems that need to be addressed: The toll system, the gate control system, and the traffic management system.

3.2.1.1. Toll Collection/Dynamic Tolling System

The toll collection and dynamic tolling system has the following operational needs:

- The toll collection system must provide a mechanism to effectively influence / regulate the traffic demand and volume in the US 74 Express Lanes by adjusting the prevailing toll rate a motorist must pay at each tolling point to use the facility.
- The toll collection system must be able to receive commands from the entity responsible for determining the prevailing toll rate, and then change the toll rate at each tolling point either up or down as directed in a timely manner.
- The toll collection system must be able to operate effectively in either static or dynamic pricing mode.
- The toll collection system, when operating in static mode, must be able to operate under a variety of static toll schedules that would be based on time-of-day (TOD) and day-of-week (e.g. weekday, weekend, holiday, emergency, special events, seasonal periods, etc.)
- The toll collection system, when operating in dynamic mode, must be able to operate based on continuously variable toll rates determined and provided by a "dynamic pricing engine" subsystem application that will render the appropriate toll rate to increase or decrease traffic demand for the US 74 Express Lanes facility based on traffic conditions.
- The toll collection system must allow for an authorized operator to manually override the prevailing toll rate as conditions warrant, in accordance with established business rules and operational policies.
- The toll collection system must be able to charge the motorist the prevailing toll rate that was communicated to the motorist upon entry to the US 74 Express Lanes facility (i.e. assign the proper toll rate to the proper vehicle).
- The toll collection system must operate in free-flow (or Open Road Tolling - ORT) traffic conditions using All-Electronic Tolling (AET) (i.e. no stopping at the roadside to pay, and no payment with cash).
- The toll collection system must be able to capture adequate necessary information about each vehicle using the US 74 Express Lanes facility such that every vehicle can be classified according to its physical attributes.
- The toll collection system must be able to capture adequate necessary information about each vehicle using the US 74 Express Lanes facility such that the proper toll account-holder or registered owner of every vehicle can be identified for payment of the toll.
- The motorist must be able to pay the toll from a standard NC Quick Pass toll account / transponder device, or a toll account / transponder device that is accepted for use in NC Quick Pass toll facilities under a reciprocity agreement.
- If a transponder device is not detected by the toll collection system on the vehicle using the US 74 Express Lanes, the registered owner of the vehicle must be able to be identified for toll payment by vehicle license plate number.
- The system operator must at all times be able to visually verify (via CCTV) the proper operation of the sign(s) communicating the prevailing toll rate to the motorist.
- The toll collection system must be safe to use, operate and maintain.
- The toll collection system must adequately and effectively support the proper revenue collection business management and operations of the state.
- The toll collection system must be accurate, accountable and easily auditable.
- The toll collection system must keep data secure from loss, theft or corruption.

3.2.1.2. Reversible Lane Operations & Gate Control System

[Important Note: Final operating policies, including hours of operation for the reversible lanes, have not been determined. At this time, the assumption is that the lanes will be open except for two short maintenance periods discussed below. Operating hours on the weekends will be flexible depending on special events and other factors.]

Since portions of the US 74 Express Lanes do not have dedicated lanes for each direction of traffic, it will therefore be necessary for the Express Lanes to operate only for traffic in the prevailing direction at designated times during the day. This mode will require the west end section (west of Albemarle Road) to operate as a reversible lane flowing westbound during the AM peak period, and eastbound during the PM

peak period. During the mid-day off-peak, the reversible lane will be closed for approximately two hours to clear the facility of all traffic before reopening in the reverse direction. During overnight off-peak hours, the reversible lane will be closed for a second two hour maintenance period and then routine clearing of all traffic in preparation for reopening in the morning. This duplicates the assumptions of the Final Traffic and Revenue Study. The eastern (2-way) section will not operate independently of the western reversible section; during the reversal period, the entire Express Lane corridor will be closed.

The reversible lane and gate system requires an interlocked, modular system that is sequenced for opening and closing the US 74 Express Lanes. Safeties must be built in so that operators cannot open a path for traffic until the opposite path is closed. In addition, manual checkpoints should be added for verification that all traffic in the corridor has been cleared.

The gate system should feature a built-in Uninterruptable Power Supply (UPS) backup to provide for continuous operation during brief power outages.

In addition to local control from the site of the gate controller, the system should be able to be operated remotely through interfaces to the system such as cell phones, RF units or Web-based interfaces with the appropriate security levels. This will allow for flexible operation and adherence to a wide range of business rules. This will also facilitate remote operations of this facility from the MRTMC and the STOC. Strong consideration could be given to allowing reversal confirmation by a vehicle operator with the assistance of a TMC operator for CCTV visual confirmation.

3.2.1.3. Traffic Management & ITS

As stated in Federal Highway Administration (FHWA) “Price Managed Lanes Guide”, “states are required to monitor the impact of SOVs on the operation of priced managed lanes to ensure that the performance of the lanes is not degraded. A managed lane is considered degraded if it fails to operate at a speed of more than 45 mph 90 percent of the time over a consecutive 180-day period during morning and evening peak hour periods.” In order to do so, there must be an effective traffic management plan to monitor, detect, and clear incidents. Therefore, the traffic management and ITS plan must do the following:

- Accommodate traffic management operations from multiple TMCs
- Support congestion management strategies for the corridor
- Support US 74 Express Lanes toll operations
- Support incident response by multiple agencies while maintaining corridor traffic management
- Build off existing Standard Operating Procedures for the Triangle Expressway as defined by NCTA’s Operations staff.

Whenever the US 74 Express Lanes are in operation, it will be necessary for the corridor to be monitored by a TMC. The monitoring TMC will need to dedicate some staff, workstation(s) and video wall to Express Lanes operations during the hours the Express Lanes are in operation. This function could be provided by the MRTMC or STOC, although technical hurdles (discussed later) exist to operating ITS devices in Charlotte from Raleigh.

Incident response will be necessary to mitigate any incident in the US 74 Express Lanes in order to meet the required performance measures. This function could be provided by either MRTMC or STOC.

The major stakeholders involved in an incident management plan for the US 74 Express Lanes corridor include:

- NCDOT MRTMC operations staff
- NCTA STOC operations staff
- CDOT TMC operations staff
- NCDOT State Farm Safety Patrols (if patrols will present on the corridor)
- Toll collection system maintenance personnel
- First Responders:
    - Charlotte Mecklenburg Police Department

- NC State Highway Patrol
- Rescue Squad/Ambulance
- Charlotte Fire Department

3.2.2. Maintenance

Since the US 74 Express Lanes have very high performance measure requirements, it is essential the infrastructure and devices supporting the Express Lanes be maintained at the appropriate levels to meet those performance requirements. The maintenance plan must include scheduled and preventative and 24/7 emergency repairs. The communications network must be provided with network management software to detect failing or failed devices with ability to self-heal the communications and maintain system continuity.

Maintenance needs for the overall toll collection system, the ITS and the gate system include identification of:

- the provider of maintenance services
- the response times and penalties for failure to perform
- critical vs. non-critical maintenance functions
- reporting requirements and reporting intervals

Specific maintenance needs and requirements for the project are listed below.

3.2.2.1. Gate Control System

The gate control system should be a very simple system that can be operated manually and automatically. Because of this feature, if an issue should occur, gates can be manually closed for repair. The gate system should be modular for ease and speed of repair.

Regular maintenance will help in preventing failures which includes lubrication, cleaning and testing. In general these gates are low maintenance items.

3.2.2.2. Traffic Management & ITS

The NCDOT ITS aerial lift trucks are limited to an approximate 40-45' working height. Any device mounted higher than that requires special arrangements to "borrow" a truck from another NCDOT unit or be equipped with lowering devices.

3.2.3. Enforcement

This project will need to define operational responsibilities for enforcement, after consultation with CMPD and SHP.

If HOV-3+ access to the US 74 Express Lanes is implemented for the US 74 corridor, an enforcement plan for such operations will need to be developed by NCTA/NCDOT. Although most agencies use visual enforcement by personnel at the roadside, automatic HOV enforcement technologies exist and may be more fully deployed by 2017.

NCTA/NCDOT to define operational responsibilities early in the design phase in order to accommodate law enforcement activities.

3.3. Coordination with Transit

The CATS routes that use the current bus lanes will be affected by the construction of the US 74 Express Lanes. This interruption will be of a short duration. However, if the pier to the Hawthorne Bridge is relocated, there could be a substantial interruption in the use of the current bus lanes until the pier work is complete.

Other planning-related needs involving transit may include setting up non-revenue accounts for transponders and coordination of possible transit schedule changes after determination of final US 74 Express Lanes hours of operation. Once operational, further coordination may be required in the event of unanticipated Express Lanes closures or changes in business rules.

3.4. System Architecture and Communications Requirements

The US 74 Express Lanes project will comply with the Metrolina Regional Report of the North Carolina Statewide ITS Strategic Deployment Plan and other associated NCDOT Regional Architecture Plans. The intent of the regional architecture is to document the flows of data between the many elements that are currently and will ultimately be deployed throughout the Metrolina Region. Based on the regional architecture, as individual projects are developed, they can be incorporated to ensure that information is shared throughout the region. If the projects proposed are not included in the regional architecture then it will be amended to have these projects included and addressed.

3.5. Financial Reporting Requirements

It is unlikely that bonds will be issued on this project. Therefore the financial reporting is relatively simple and mostly internal to the NCDOT. The project will be included as a new section of the following NCTA general reporting requirements:

- CAFR (Comprehensive Annual Financial Report)
- Annual and semi-annual reports to the General Assembly
- Quarterly NCTA operations and maintenance reporting (BOS, RTCS & ETCS, ITS, etc.)
- NCTA annual operation budget
- NCTA Board of Directors would need to approve toll rates, policies, and/or adjustments

3.6. Express Lanes Business Rules & Operating Policies

The business rules for the Express Lane System must consider the reversal process, maintenance process, High Occupancy Vehicle (HOV) access, and hours of operation. Facility operational policies should be compatible/consistent/coordinated with those of adjacent similar and/or related tolled facilities. Although some assumptions of business rules are contained within, these will be developed in conjunction with other rules and policies defined by others. The Concept of Design and Operations Report will not define or elaborate on final business rules or policies.

NCDOT/NCTA will identify and finalize Business Rules and Operating Policies

4. TOLL INFRASTRUCTURE, ITS & SIGNING DESIGN

The purpose of this section is to explain certain design decisions made in production of the Conceptual Plans in the fall of 2014 and to explore other design issues in order to prepare NCTA for final design. Signing, ITS and toll infrastructure final design may be performed under NCTA contracts or other NCDOT on-call contracts. Alternatively, they could be turned into a Design-Build contract.

Unless otherwise noted, the tolling, ITS and signing design should be consistent with existing practices on the Triangle Expressway as expressed in ITS and AET Standard Drawings, and recent toll project Scopes of Work. For example, toll zone lighting standards would remain the same.

4.1. Roadside Toll Facilities Infrastructure

4.1.1. Civil Infrastructure to Support RTCS

It was determined that a long term onsite power backup (e.g. with generators, as currently deployed on the Triangle Expressway) is not required for the project for the following reasons:

- Power service along the corridor has a reliable track record
- Due to nature of Express Lane operations, a majority of revenue generation will likely only be taking place during peak periods

Furthermore, without the need to service the generator or provide a pull-off for generator fuel trucks, a dedicated pull-off for the toll site is not required. A three-hour onsite UPS is advisable. In the absence of a connection with the Toll Zone Host and/or BOS, transactions are buffered and can be stored locally for an extended period of time (for the Triangle Expressway, up to 90 days).

With the toll building eliminated, and because it is likely that only two “lanes” will be fully instrumented in each direction, all tolling equipment (including the UPS) can and will be mounted either overhead on a gantry or within the cabinets located in the median. Lane controllers should reside in cabinets, not gantries, to facilitate upload/download from maintenance personnel. The deletion of the building, pull-off, generator and fuel tank will result in substantial cost savings.

4.1.2. Gantry Considerations

The gantry design chosen for the Concept Plans uses a single gantry for each tolling point rather than the dual gantries used for the Triangle Expressway. This design was recommended for the following reasons:

- Lower cost
- Lack of strong aesthetic considerations for this project
- No functional shortcomings versus dual gantry

Consideration should be given to exploring the triggering of cameras and definition of vehicle classifications from above the lanes, with gantry-mounting equipment. However, it is recommended that the initial US 74 installation use in-pavement loops, as is used on the Triangle Expressway. However, see Section 5.3.1 regarding instrumentation of the shoulders.

4.1.3. Standards and Documentation

NCTA has created (and continues to develop) a set of AET Standard Drawings that show in detail the infrastructure requirements for the toll zones. Part of the US 74 Express Lanes effort should include the

updating of these standard drawings with new details customized for Express Lanes. This should also include details for a reversible tolled lane.

Update NCTA AET Standard Drawings with details appropriate for Express Lanes.

4.1.4. Separation of General Purpose Lanes from Express Lanes

In the east half of the project, where the US 74 Express Lanes exist side-by-side with the general purpose lanes, flexible pylons will be used to separate traffic. Such flexible pylons have the advantage of being able to be driven over by emergency vehicles or vehicles in distress. Experience with Express Lanes projects nationwide has shown the need for the flexible pylons to be spaced 10' apart (in conjunction with a 4' wide lateral buffer zone) in order to prevent vehicles from weaving in and out of the Express Lanes.

Flexible posts will incur significant maintenance costs (versus no posts, or concrete barrier) due to the ease with which they can be damaged or destroyed. Operations and maintenance cost estimates should allow from between 100% to 150% replacement of posts in the system per year.

4.1.5. Ingress/Egress to Express Lanes

TGS Engineers is designing ingress and egress points to the Express Lane system. These points can be been clearly seen on the Gate Control System concept plans in **Appendix A**, sheets 9 through 12.

4.2. Gate Access Control System

Due to the conversion of the existing two-way bus lane to a single reversible Express Lane, the opportunity exists for motorists to unintentionally enter the reversible lane, headed in the wrong direction. Therefore, an access control gate system is envisioned to guard against such a situation. Gates will be strategically placed to prevent incorrect ingress or egress in areas during single direction flow.

The conceptual layout of each of the four gates systems is shown in **Appendix A** (sheets 9 thru 12).

The access control gates can be barrier or ground mounted with varying lengths of arms depending on the geometry at the current segment. The preference is to install the communication equipment and power for the gates in the right of way and if possible, in or on the barriers. Based on the geometry, installation will require site specific accommodations. The load on the standard barriers should not require any modifications to provide support. If narrow, non-standard barrier is used, its ability to provide sufficient support will need to be assessed and confirmed.

The proposed gate system is recommended to feature the following characteristics:

- High visibility gates with staggered arm lengths to deter vehicle entry (see **Figure 2**)
- Maximum 100-foot spacing between gates
- Provide single gate controller box for each of the four system locations
- Provide communications from gate to the controller box in a communications conduit (typically 1") (This can also be linked via fiber to the other locations for coordinated command and control)
- Distribute power to all gates at a single system location through a power conduit (typically 1" or 2")
- Provide interlocks using software and hardware logic to prevent the ingress or egress from opposite directions to be open at the same time
- Utilize ITS fiber-optic trunk line system from the gate controller to the main command and control location (the MRTMC or the STOC) where the reversal will be initiated and monitored
- Utilize power from a new local drop from the power company
- Embedded UPS back-up (upon loss of power, gates stay in last state)

Figure 2. Typical High Visibility Gates for Gate Control System

4.3. ITS

This project is unique because the ITS devices (CCTV, MVDs and DMS) will support traditional NCDOT and CDOT traffic management operations and as well as provide data to NCTA for the US 74 Express Lane operations.

The ITS conceptual plan is shown in the **Appendix A** (sheets 4 thru 5). The ITS system will include the following features:

- All devices will use redundant (fault tolerant) Ethernet communications over fiber-optic cable.
- Provide communications and power through four (4) 1.25" conduits that exist between I-277 and Albemarle Road.
- Provide communications and power through four (4) 1.25" conduits between Albemarle Road and the east end of the project, installed by U-209B.
- Distribute power from Duke Energy to all devices using the above conduits, where necessary and advisable. Conduits will be routed through separate pull boxes.
- Provide cameras mounted 40-45' high for access by NCDOT or toll system integrator (TSI) trucks. The new CCTVs will be collocated on existing poles, where available, with the CDOT CCTVs. For other locations where CDOT CCTVs do not exist, there will be new poles. The new CCTVs will utilize the CDOT cabinets where available.
- The CCTVs located in the I-277 and US 74 interchange may need to be installed on 60' poles with lowering devices to facilitate adequate viewing.
- CCTVs will be located to verify the toll rates posted on the DMS for US 74 Express Lanes system.
- All proposed devices will use separate fiber-optic strands from those allocated to CDOT.
- All MVDs will be installed on existing or proposed poles or collocated on existing sign structures in accordance with the manufacturer's recommendations. Depending on the available right of way and setback distances, one or two detectors may be required.
- The existing DMS on Albemarle Road will be relocated to a new sign structure on US 74 at Westover Drive.
- The existing DMS on US 74 near Wallace Lane will be relocated to a new sign structure further east to accommodate sign spacing needed for the Express Lane approach signing. Since this location is beyond the limits of the initial deployment of the US 74 Express Lanes, the sign will use either wireless or dial-up telephone communications.

NCDOT and CDOT are already sharing the fiber-optic communications network and have an agreement for allocation of the cable assets. In the first phase of the Express Lane deployment, the communications infrastructure must consider subsequent phases that expand the project further east to I-485. While there is

capacity to add the Express Lane operations, communications carrying toll transaction data is generally carried on a physically separate and more secure network and that is recommended for this project. Although a single 72-fiber cable is proposed for the project, separate buffer tubes will be dedicated for US 74 Express Lanes use, and for non-Express Lane use. Currently there are discussions with CDOT to install a "starter cable" in the U-209B conduit for CDOT use; this would get CDOT devices/nodes (including traffic signals) online earlier than the proposed completion of U-5526A.

Since the ITS data and video will be shared there must be servers locally to facilitate that sharing. These servers will host the appropriate control software and any stored data and video images. It is estimated the required servers for ITS and communications equipment will occupy no more than one full-size communications rack.

The equipment requires a secure and climate-controlled environment with Uninterruptable Power Supply (UPS) power and direct access to the fiber-optic network. The MRTMC has a secure server room, UPS power, and a generator backup, and is directly connected to the fiber-optic network. The UPS system was recently replaced and should meet any new back-up power needs. The MRTMC staff is removing the last of the old CARAT (Congestion Avoidance and Reduction for Automobiles and Trucks) system equipment which will free up one communications rack in their server room.

4.3.1. Communications Redundancy

CDOT reports the potential exists for constructing a redundant ring communications path for the corridor that would parallel US 74 by running down Monroe Road. Further investigation is needed to determine the cost-benefit of this possibility.

Investigate communications redundancy options with CDOT.

4.4. Signing and Marking

A detailed sign schematic was prepared in Phase I and is contained in the **Appendix A** (sheets 1 thru 3). The concept coverage area includes the US 74 Express lanes, the general purpose lanes, and the roadways leading up to the Express Lanes. The sign system is designed to provide specific lane management information to motorists approaching and utilizing the Express Lanes, as well as navigation information for all users. Dynamic and static signs will operate as a system to convey necessary information for the operating strategy.

4.4.1. Signage

The signing plan contains three categories of signs:

4.4.1.1. Express Lane Dynamic Signage

The signing plan includes a series of dedicated DMS placed in advance of ingress points for posting of toll rates, and for denoting when the US 74 Express Lanes are closed. High resolution (34mm pixel spacing) color dynamic signs will be used because they offer better legibility and ability to display easily recognizable regulatory and warning sign symbology. Fixed CCTV cameras will be deployed in advance of signs to monitor toll rates changes.

4.4.1.2. Static Signage

Static signs will be used to communicate regulations, which are based on the business rules. The signing concept plan also proposes revised static signs incorporating "Express Lanes" terminology.

4.4.1.3. DMS for Traffic Management

Several new or relocated DMS along the corridor dedicated to traffic management activities; these signs are discussed in Section 4.4.

4.4.2. Pavement Markings

Pavement marking design will be handled by the final design plans. All pavement marking shall be in accordance with Section 2G of the Manual of Uniform Traffic Control Devices. Consideration should be given to adding pavement marking standards for Express Lanes to the NCTA and/or NCDOT Standard Drawings.

4.4.3. Coordination and consistency with other projects

Efforts are underway to coordinate the signing of the US 74 project with the I-77 Express Lanes P3 project and the Monroe Expressway. The close proximity of these three projects creates the possibility for customer confusion if the signing plans are not reasonably coordinated.

Proactively coordinate with I-77 Express Lanes and Monroe Expressway projects to create signing concepts consistent with one another.

5. All-ELECTRONIC TOLLING (AET) SYSTEM

The AET system forms the heart of the US 74 Express Lanes project and requires a detailed examination.

Currently NCTA operates only a single toll road, the Triangle Expressway. To create and manage the operation of the AET toll collection system, NCTA created a series of contract procurements:

- The RTCS procurement: this contract included the design, factory acceptance testing, installation, site testing and implementation of the RTCS roadside equipment (loops, scanners, cameras, lane controllers, servers, communications, etc.). This contract also includes maintenance of the RTCS, ITS equipment, and toll zone facilities (e.g. the toll vaults).
- The ETC procurement: this contract included the ETC design, coordination with the RTCS contractor for installation and testing of the ETC equipment (antennas and readers) and the purchase of vehicle transponders.
- The BOS procurement: this contract included the design, factory acceptance testing, installation, site testing and implementation of the back office toll processing system, including customer account management, RTCS transaction processing, system operational and financial reporting, interoperability interfaces, invoicing, data back-up, web page, IVR, OCR and the ability to add additional NCTA projects.

Each of these contract procurements will need to be repeated for the US 74 Express Lanes project, or else the existing contracts modified. Modifications to these contracts, for work unrelated to the Triangle Expressway, are known as Extra Work Orders.

A fourth contract, the Operations procurement, provides staffing and management of the business side of the BOS, including establishing and maintaining accounts, and overall customer service operations but is not directly tied to the toll collection system. However, the additional staff may have to be added to the CSC to cover the increased customer base account management requirements. In addition, the CSC storefront in the Charlotte area will also have to be staffed. The Operations contract can be amended to accommodate these added personnel requirements.

Further study the Operations contract to determine additional personnel needs, including for the Storefront.

5.1. High Level System Architecture/System Overview

Toll zone collection system components can be divided into three groups:

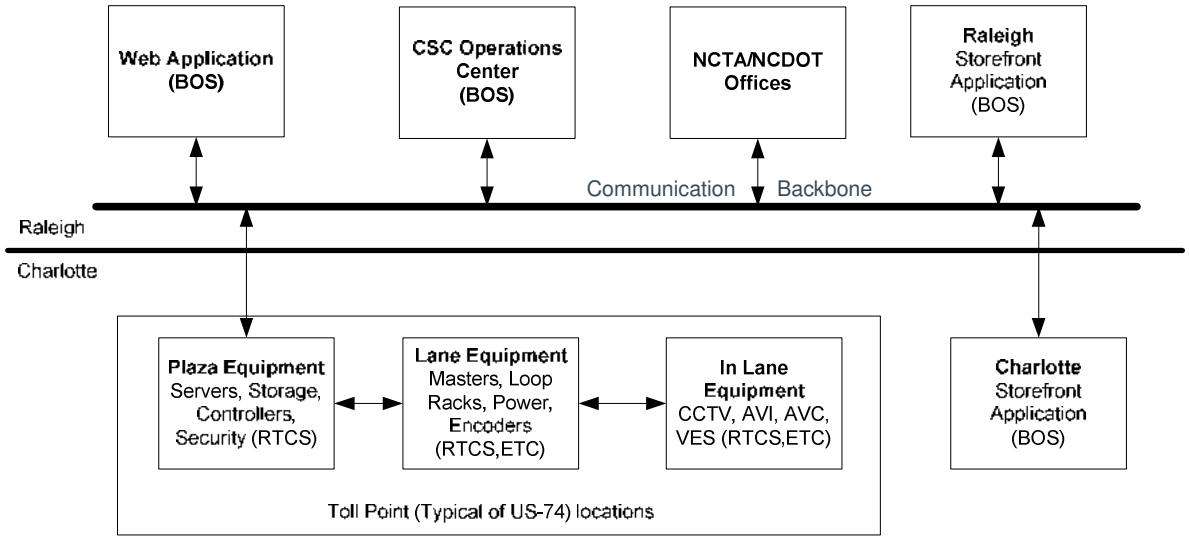
- “In Lane Equipment”: Components such as loops, antennas, cameras, classification devices and scanners located in the pavement or mounted on a gantry
- “Lane Equipment”: Components that are mounted inside roadside electronics cabinets such as loop detector racks, device masters, Ethernet switches, power supplies and PDUs.
- “Plaza Equipment”: Components including Lane Controllers, Plaza Host, communication servers, etc.[1]

In each category, some of the equipment is supplied by the RTCS Contractor, and some by the ETC Contractor.

[1] Reference XEROX DDD, Section 2.3, 11/4/2010

A general system overview of the proposed TCS for US 74 Express Lanes is shown in **Figure 3.**

Figure 3. Toll Collection System General Overview

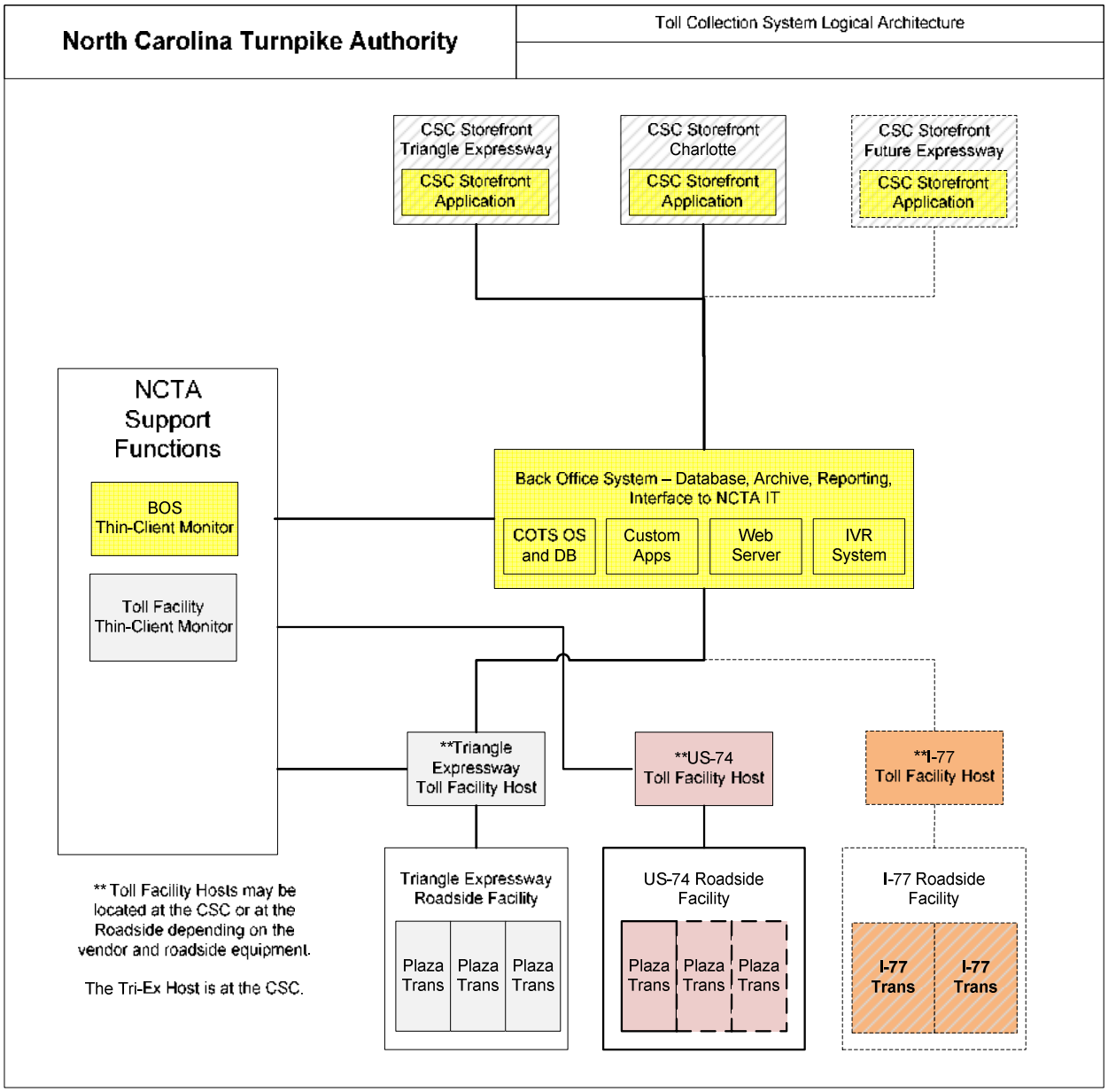


The Plaza Equipment could be located at the roadside, but since a more secure local facility (the MRTMC) exists, that is the preferred location.

The AET solution to be deployed at the new toll zones will be designed to meet the US-74 Express Lane requirements. The architecture of the initial project will be simple and will be designed to be expanded as additional segments/phases are added to the US 74 project. This solution must therefore be a field-proven flexible, scalable and modular solution. This includes redundant components, servers, and technologies, given the remote location from the Triangle Expressway and the relatively small footprint of the installation.

Expansion of the US 74 solution to other Express Lanes projects throughout the state can provide for a reliable, repeatable Express Lane solution with predictable results. The desire is to develop the right solution for North Carolina for this smaller project so that it can be replicated as a proven solution on the larger projects.

Figure 4. Toll Collection System Logical Architecture



5.2. Specific Components of Toll Collection System

5.2.1. Detailed Approach to Trips/Transactions

Trips and transactions go hand in hand throughout the system. The transaction is the smallest recorded indication that a vehicle has passed a read point (roadside tolling location). The effectiveness of the system depends on the accuracy and consistency of the read point.

Initially US 74 Express Lanes will be a point-based installation since there is only a single tolling point; there is only one (1) entry point and one (1) exit point for a “trip”. The transactions recorded will represent a long

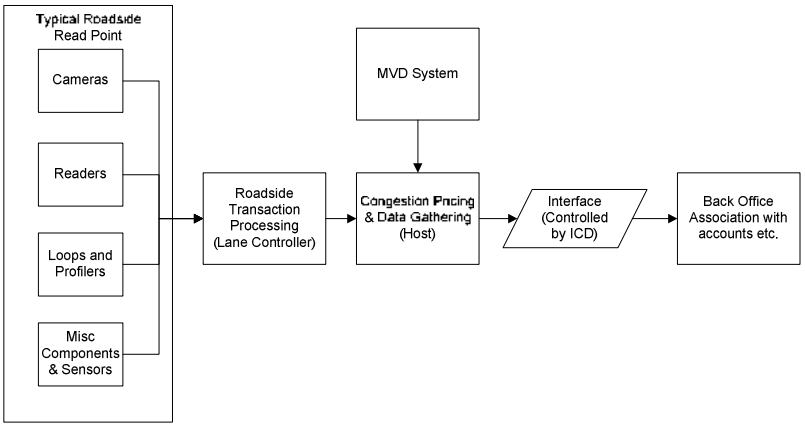
trip (Wallace Road to I-277, or the reverse) or the short trip (I-277 to Albemarle Road, or the reverse). There is no trip-building. As future sections of US 74 Express Lanes are added, this would introduce additional Origin-Destination (OD) pairs. Transactions are compiled into trips by recognizing the Origination and Destination. These trips are priced in the system as the number of types of trips is finite. When the trips are on a long segment of roadway (e.g. 20 miles) the OD Pairs are broken down into smaller components called segments. These segments are then captured in manageable lengths. This will be accomplished through the trip building software and is scaled up as more road segments come online.

5.2.2. Data Flows and Interfaces

The data in the tolling system originates at the roadside and is packaged and sent to the Back Office System. The methodology of the calculations, combination and transmission from roadside to Back Office can take various forms. There are some important commonalities that help the flow of data and define the methodology to support the common Back Office System.

- The data collected from any roadway sensor or equipment is used to create a properly formatted transaction message.
- Communication to the Back Office System will be through leased facilities, as no dedicated fiber network connects from project site back to the CSC (see Section 2.3.3.3)
- Trip formation is intended to occur prior to shipment to the Back Office, if and when trip formation is required for the full build-out.
- All transactions should be processed at the Back Office and assigned to customer records.
- Statistics will be tracked for each corridor, toll point or trip for reporting purposes.

Figure 5. Transaction Flow thru Toll Collection System



5.2.3. Telecommunication/Broadband Systems

To send toll transactions to the CSC in Morrisville, a high speed communication connection will be required. Several options exist for this connection:

A) Install fiber from the Host/Plaza site to the CSC (currently missing major portions on interstate route corridor),
B) Provision a dedicated/private leased line connection from the (Roadside) project site,
C) Provision a dedicated/private leased line connection from the MRTMC, or
D) Utilize a connection via the NCDOT IT network from the MRTMC.

In conversations with the NCDOT State IT group, it appears that the preferred option is to provision leased circuits at this time, originating at the MRTMC (Option C). Option A is not financially realistic and would be subject to a host of schedule-threatening risks. It is doubtful Option D could provide the Quality of Service

(QOS) needed for the project; in additionally implementing this solution according to the required timeline would be unlikely. Option B is acceptable but is inferior to Option C as the MTRMC offers a secure and robust/protected environment to host equipment, as well as on-site back-up power. In addition, the US 74 Toll Point is not a good concentration point for future Express Lanes projects in the area. Option C would leave open the possibility of utilizing a state-owned network in the future should one become available. As future Charlotte projects are added the communication options may change as the North Carolina communication infrastructure evolves. Proper selection of equipment made up front would prepare NCTA for eventual upgrades and migration to future changes.

Pursue leased line communications from MRTMC to CSC for toll collection system. Investigate detailed bandwidth requirements.

5.2.4. Dynamic Tolling Software

Dynamic tolling software is used as the term to analyze the traffic flow, volume, and level of service on the roadways by utilizing mathematical means to compute the best pricing to move some of the vehicles from the general purpose lanes to the US 74 Express Lanes. This balancing act will alleviate some congestion on the general purpose lanes and enhance the ride for all lanes.

5.2.5. Express Lane Tolling Algorithm

The US 74 Express Lanes dynamic tolling algorithms will be founded the following principle:

- Dynamic Tolling: The per-mile rate charged to patrons will vary throughout the day, based on the level of congestion in both the Express Lane and in the general purpose lanes. The toll will increase as congestion increases, in order to ensure that an average speed of at least XX (e.g.45 or 65) miles per hour (mph) is maintained in the Express Lane, 90% of the time.

5.2.5.1. Key Variables

The following are critical to the function of an Express Lane dynamic tolling algorithm. The appropriate values assigned to all variables must be determined and approved by NCTA prior to implementing an Express Lane algorithm.

- Standard Value of Travel Time: This value, expressed in terms of cents per minute, is used to calculate the value of travel time savings provided by the Express Lane. This value can be used to determine the cost of the patron's time saved. A typical value used in other systems is 40¢/minute (equivalent of $24/hour).
- Minimum Acceptable Average Speed in the Express Lane: This value represents the minimum average speed that NCDOT/NCTA would like to maintain in the Express Lane. It is a proxy for Level of Service. If the average speed in the Express Lane falls below this value for two consecutive evaluation periods, (Typically set to minutes, 5, 6, or 10, based on system geometry) then the toll for all upstream locations will increase. For a system like US 74, this may be 55 mph based on closed system and roadway speeds. (Values from 45 to 65 have been used in other systems.)
- Incremental Increase to Value of Travel Time: This value represents the extent to which the base value of travel time will increase in the event that the "minimum acceptable average speed in Express Lane" (as described above) is not maintained for two consecutive evaluation periods. This increase would be applied to each entry point that is upstream of the deficient Express Lane segment. This value is typically in ¢/minute and may range from 2¢ to 20¢, based on other implementations of this practice.
- Minimum Rate per Mile: This value represents the minimum fare that will be assessed to patrons using the US 74 Express Lanes. It will typically apply during the overnight or low use periods, when overall traffic is light and the Express Lane and would likely yield little or no travel time savings. This variable can be flexible so that NCTA can vary it by hour. Busy travel periods should have a higher minimum rate per mile than off-peak periods. The values used in various systems range from 10¢ to 35¢/mile (peak), 2¢ to 8¢ /mile (off-peak) depending on the location, volume and geometry.

- Maximum Rate per Mile: This value represents the maximum fare that will be charged to patrons entering the US 74 Express Lanes. If the calculated rate (based on travel time savings) is greater than the maximum rate, then the Express Lane control would then close the access point to Single Occupancy Vehicles to relieve the stress on the Express Lane. Typically there would be a maximum of something similar to $1.00 per mile. (This value must be set by NCTA and NCDOT to be consistent with the rate structure of the roadway or roadway segment, in which a maximum fare of $6 is charged to patrons traveling the full length of the 6-mile reversible lanes.)

5.2.5.2. Algorithm Calculations

The algorithms for US 74 Express Lanes calculate the appropriate fare utilizing the pricing variables applicable to the system, the general purpose lane speeds, traffic volumes, and target service levels, as compared to the same Express Lane variables:

- The US 74 general purpose and Express Lanes are typically divided into segments. For the US 74 initial project there would be a single segment for the initial 6 miles and additional segments added as the remaining portions of the road are completed.
- Average speeds are typically calculated at a minimum of two locations on each segment or more locations on longer segments. Since US 74 is 6 miles in length with a short trip and a long trip, traffic sensors are will be at key locations along the route to calculate the average speeds, volumes and level of service for both the Express Lanes and the general purpose lanes.

Some additional considerations for the calculations:

- Base Rates – Minimum and Maximum Rates charged for trips (US 74 initially has a long and short trip).
- Multiplier/Weighting – Defines a weight or a multiplier that can be applied to adjust the rate based on traffic density.
- Density-Based Rates – Defines density limits and considers other traffic readings downstream in setting the rates.
- Speed-Based Rates – Computed for a segment, compares Express to general purpose Lanes with a minimum and maximum rate.
- Default Traffic Data Rates – Time and day based plan that uses historical density in the event of information loss or degraded mode.
- Override Plans – Special considerations for events, weather, etc. The adjustments based on speed and density are not considered. Usually manually set based on the event.
- Daily Trip Rates – Special plans for daily commuters if desired. This may include CATS and incident response teams.
- Daily Segment Pricing – Special plans for daily commuters on smaller segments known for heavy commuting but smaller segments. (Future application of this may apply.)
- Default Rates – Determines what should be charged based on certain criteria such as failure conditions, loss of communications, etc. Usually based on historical averages and can be the rates charged if there is a degraded mode operation.

North Carolina does not currently have a system that concentrates the traffic sensors and provides the proper information to a dynamic tolling system. It is highly unlikely such as system would be procured soon enough to meet project schedule needs in the near future.

5.2.5.3. Location of Dynamic Tolling Hardware/Software

The calculations to determine dynamic tolls are based on information collected from the US 74 general purpose and Express Lanes along the length of the corridor. Considerations must be given to the data collection point through vehicle sensor devices (MVDs) and concentrated for use in various locations. The following locations should be considered during design for optimum performance.

Local to Segment	The traffic data from the MVDs is read at the local roadway at the Express Lane and general purpose lanes and then concentrated and fed into the pricing algorithm. This information would also be important to the TMCs and could be forwarded to the TMC to be concentrated for display and use. The specific calculations needed for the tolling algorithms would be taken from the concentrators and computed. Then the pricing would be sent to the DMSs and the toll system.
Nearest TMC	Currently traffic data is being collected at the MRTMC and STOC. The current systems are not configured to provide the required parameters necessary for the rate calculations. This could be mitigated by installing the proper systems. Installation of independent data concentration for the MVDs on the US 74 Express Lanes would keep the ITS and Toll systems separate while providing the inputs necessary to the Dynamic Tolling Algorithm.
Customer Service Center	The BOS in the Customer Service Center has been designed to support account processing from any type of toll system, all-electronic or with cash collection, point-based tolling or a trip-based system, but not to actually calculate trip-based tolling (as per the original contract). The CSC is not currently connected to the MRTMC or the roadways in Charlotte. This presents a communication and possible Loss of Service issue that could hamper operations on the remote roadways. For reliability it is recommended that the Dynamic Tolling Algorithm application and the data collection be in close proximity of the corridor.
Another Location	It may also be possible to have additional locations where there are remote data collection components as part of the ITS system that could connect the data needed from the Express and general purpose lanes. This may also be considered but poses logistical issues.

Table 1. Possible Location of Dynamic Tolling Hardware

Because of the remoteness of US 74 from the CSC and Back Office System and the need for leased lines for communication, the dynamic tolling hardware and software would be more effective if housed in the area of the corridor (at the roadside or the MRTMC).

5.2.6. Dynamic Tolling Software System Procurement

The possible alternatives (pros, cons, risks) for procuring and deploying standalone Dynamic Tolling Software (DTS) each have their own considerations.

Dynamic Tolling Software Procurement Matrix			
Method of Procurement	**Pros**	**Cons**	**Risks**
To have the Dynamic Tolling Software built into ITS design project and provided by ITS vendor like the maker of the detection devices	• The devices that are used will have effective interfacing to the Dynamic Tolling Software. • This would have a single point of responsibility for the Pricing Algorithm. • Part of a competitive bid	• If the vendor is chosen for US 74, this could give that vendor higher consideration for a statewide procurement of an ITS statewide system. • The sensors may be limited to the vendor chosen.	• Control of the vehicle detectors is in the control of the vendor and not the TMCs
Standalone procurement and deployment of Dynamic Tolling Software by vendor	• The experience of existing implementations would make development of the Dynamic Tolling Software quicker • Competitive bid	• Vendor would be locked for a period of time. (typically 5 years) • Time to get to a procurement and installation from RFP could be as long as 18 months.	• May not be able to make the opening of the US 74 segment • Interface to the tolling system must be seamless and may not be completed in the proper amount of time.
Extra work order for BOS Contractor to develop and deploy Dynamic Tolling Software at the CSC (BOS)	• The existing tolling system is defined by RFP to be capable of handling Dynamic Tolling Software models • Procurement time would be reduced as a negotiated extra work order	• BOS Contractor would be responsible for the Dynamic Tolling Software. There are current minor issues with the system that have not been repaired, how would this be handled. • Not competitively bid	• Communication to the main CSC for dynamic tolling would need constant communications and reliability.
Extra work order for BOS Contractor to develop and deploy Dynamic Tolling Software at a roadside Host or at the MRTMC.	• Interfacing to the CSC system should be seamless since the system has been designed and implemented by BOS Contractor • The use of a single pilot Host implementation would allow for learning the best method of implementation for future projects.	• BOS Contractor would be responsible for the Dynamic Tolling Software. There are current minor issues with the system that have not been repaired, how would this be handled • Not competitively bid	• Local systems must be maintained by BOS Contractor and would require knowledgeable personnel at the site to maintain the Dynamic Tolling Software or high speed remote access
Procurement for RTCS Contractor to develop and deploy RTCS/DTS at a roadside Host or at the MRTMC.	• Competitive bid • Economies of scale could be achieved by combining the US 74 and Monroe RTCS procurements	• Time to get to a procurement and installation from RFP could be as long as 18 months.	• May not be able to make the opening of the US 74 segment

Table 2. Dynamic Tolling Software Procurement Options

5.2.7. Recommendation of the Preferred Method

In the Fall of 2015, NCTA had HNTB conduct a more in-depth study of procurement options for both the dynamic tolling software and the RTCS as a whole. The conclusions of this effort were:

- Combining the RTCS procurement for the Monroe Expressway & RTCS procurement for the US 74 Express Lanes; and
- Sufficient lead time and total contract time exists to procure the dynamic tolling software and the RTCS for US 74 and Monroe.

Pursue Request for Proposals for Charlotte Region RTCS, including Dynamic Tolling Software

5.2.8. Procurement Details and Scheduling

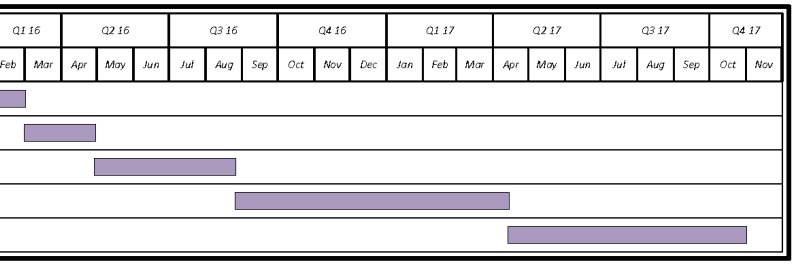
The procurement of the Dynamic Tolling Software and integration to the BOS at the CSC is on the critical path for any Express Lanes project in North Carolina. The procurement methodology may be negotiated or open bid. Each of these methods have their timelines and must be considered as a key component for implementation of each Express Lane system. **Figure 6** shows the proposed timeline of the project; only the portion applicable to US 74 Express Lanes is shown.

It should also be noted that there is some probability that the US 74 Express Lanes project will be delayed in order to sync the opening with the follow-up project, U-2509.

The State of North Carolina has project constraints to procure such a software system which would fall under the EPMO Office and trigger the gate approvals in the state management process. This will require constant management and attention to meet the US 74 deadlines. For more complete information on the EPMO/State IT requirements, see Section 5.5 and **Appendix E**

Figure 6. Proposed Dynamic Tolling Software & RTCS Project Schedule

ID	Task Name	Start	Finish	Duration
1	Prepare RFP & Advert	10/1/2015	3/1/2016	109d
2	Proposal Preparation	3/1/2016	4/29/2016	44d
3	Prop Review & Nego.	4/29/2016	8/26/2016	86d
4	NTP thru Design	8/26/2016	4/14/2017	166d
5	FAT, SAT thru Go Live	4/14/2017	11/1/2017	144d



The project would be required to meet all EPMO/State IT requirements for all phases of the project. See **Appendix E** for further details.

5.3. Roadside Toll Collection System Component

With the US 74 project being a single tolling location with two (2) bidirectional tolling points, the system footprint is minimal. Because this is a “starter project” a full procurement would be expensive compared to the actual implementation of the roadside equipment. However, combining the procurement of the RTCS with the RTCS procurement for the Monroe Expressway will achieve economies of scale. The timelines of the two projects overlap enough to make such a combination viable. This would create a “Charlotte-Area RTCS vendor. For future procurements, NCTA would have the choice of a new independent procurement or an Extra Work Order with the local/regional vendor.

With the procurement comes various phases that are already vetted in the Triangle Expressway installation. Utilizing the same general configuration as the Triangle Expressway, as well as re-using certain hardware,

would greatly simplify the production and review of the Preliminary Design Submittal, the Detailed Design Document, and other such costly efforts. Factory Acceptance Testing will largely be eliminated. Site Acceptance Testing would be under the same conditions as the transactional point system as in the Triangle Expressway since the system is basically two tolled points at the same location. The testing of the reversible installation would require testing in both directions of all roadside features.

Expansion of US 74 to I-485 would require modification of the definition documents, ICDs, algorithm definitions, legislation, business rules, etc.

The ultimate vision of NCTA is that for all large projects such as the upcoming I-485 Express Lanes, the presumption is that there would be a separate procurement for RTCS even if the BOS is retained under the current vendor. This will be possible if detailed and accurate interface requirements are defined in the procurement.

5.3.1. Roadside Toll Collection System Infrastructure

Two mast arms located 40- to 60-feet apart (one for each toll point) in the median slope pavement area will provide appropriate mounting for the overhead tolling equipment (see **Appendix A**, sheet 7 - Toll Site Overview). Outriggers and brackets mounted to the cantilever arm provide the needed separation for the tolling equipment for both directions. Refer to the cross-section, side view and top view included in **Appendix A,** sheet 8 – Toll Site Details.

Implementing the tolling solution in the US 74 Express Lanes brings up the question of instrumentation of the shoulders. Because of the nature of the operation the following is considered:

- The width of the shoulders may allow vehicles to bypass the toll point.
- Speeds through the Express Lanes are expected above 45 mph.
- Hours of operation are projected to be limited, and therefore limit the exposure potential to evaders.
- Installation of mitigation devices such as rumble strips or other devices would deter violators from going around the toll point while leaving a path open for emergency vehicles as needed.
- Cost of fully instrumenting a lane of bi-directional tolling can range from $120,000 to $200,000 per lane depending on the vendor. Given a toll of $3.00 it would take 40,000 to 67,000 vehicles bypassing a toll point to break even for the cost of just one shoulder of instrumentation.

The US 74 Final Traffic and Revenue Study projects approximately 650,000 yearly Express Lanes trips at ramp up. If 1% of the vehicles are estimated to avoid the toll by using the shoulder, that would yield 6500 trips. These trips will conservatively pay about $1.50 per trip in tolls, netting $9750 in lost revenue per year.

The capital cost of instrumenting the two 10’ shoulders with bi-directional toll lanes is $240,000 to $400,000. Payback for the lanes would be 25 years to 40 years. The life expectancy of the toll system is 10 years maximum, which would therefore appear to support a case to not instrument the lanes. Installation of cameras should be considered as part of the Digital Video Auditing System (DVAS) to capture violators but full instrumentation does not appear to be financially sound in this small installation.

For these reasons, it is recommended that the shoulders not be fully instrumented at this time. Instead, partial instrumentation (with cameras and out of pavement detection) can be deployed.

5.3.2. Roadside Toll Collection System Equipment (non-ETC)

To implement the proper solutions for the Toll Collection System, sufficient infrastructure and support equipment is necessary. This may include the implementation of:

- AVC System – Automatic Vehicle Classification such as loops, profilers, laser scanners or stereoscopic classification devices.
- VES – Vehicle Enforcement Systems to capture front and rear license plates. This can be either over lane or side fire mounting with flash.

- Lane Controller systems – This would most likely be a redundant computer-based lane controller. Because of the nature of the computers and the climate in Charlotte, there will need to be air conditioning in the roadside cabinets.
- CCTV System – To visually see the condition in the lanes and verify that the toll zones are functioning from a remote location; also, to confirm toll rates on toll rate DMS panels.
- DVAS – This system is an integral part of most highly auditable systems. For the installation for the Express Lane systems, installation of a permanent DVAS system may be overkill and put undue cost on the systems. The provisions for a portable DVAS system that can be fully integrated without changes to hardware and software would allow periodic audits of the locations for compliance and identifying issues. This could be moved to other sites as they are brought online as the roadway expands.

It is unknown at this time whether trucks will be allowed on the US 74 Express Lanes. If they are allowed, the RTCS will capture images for both front and rear license plates for every transaction, and machine process (Optical Character Recognition "OCR" or Automated License Plate Recognition "ALPR") the images to collect vehicle identification information which is added to the transaction message. When both front and rear images are captured, they are matched as a single vehicle transaction. An image will be captured for each front license plate area, whether or not the vehicle has a license plate. If the business rules forbid truck traffic, the front camera image functionality will be omitted. The local plaza stores audit video that can be queried as research for transaction investigation. If the license plate images are not recognized at the plaza level, they are transmitted to the Image review location for processing as a potential new customer and added to the Back Office System. The toll system logical architecture can be seen in **Figure 4.**

Each toll zone will incorporate a CCTV overview camera that is time-synchronized to the toll system and provides a total field of view of all tolled lanes in the zone.

As the US 74 toll points are integrated to the existing Back Office and Customer Service Center, additional support will be required:

- A Host System to concentrate and store data near the US 74 project (may be at the roadside, MRTMC or other location)

- Communication of sufficient bandwidth must be established from the Customer Service Center to the local storefront, the Roadside and the MRTMC.

5.3.3. Electronic Toll Collection (ETC) Equipment

Based on the geometry of the corridor, the US 74 reversible toll collection point is proposed to be installed at the intersection of Albemarle Road and US 74 to capture transactions. This is a strategic location that provides for a single location along the 6 miles of project that must be passed by all drivers in the US 74 Express Lanes. The equipment necessary to provide ETC at this location will need to be procured, and will cover all tolled lanes. Due to the scope of the project, it would not be cost effective to consider a separate procurement for ETC. It is anticipated that general design guidelines for ETC at the roadside will follow standards set for the Triangle Expressway.

The RTCS will use an ETC system compatible with the one provided by the current NCTA ETC contractor. The ETC system will function/interoperate with any of the major ETC systems on the North American market (initially with TDM and eGo (and its subset, SeGo) protocol). If the ETC system should malfunction, the tolling points will function as a video-only toll facility.

Although operating policies have not been finalized, it is likely that HOV-3+ vehicles will be allowed to drive toll-exempt on the US 74 Express Lanes. Such vehicles would need a declarable/switchable transponder to allow the driver to declare him/herself toll-exempt if the HOV requirement is met. These type of transponders are not part of the NCTA inventory at this time.

Pursue an Extra Work Order with ETC Contractor for ETC coverage of new tolled lanes and for declarable transponders.

5.3.4. Roadside Toll Collection and Gate Control System Maintenance

Routine or preventative maintenance of the overhead and in-pavement tolling equipment would be accomplished during off-peak/closed times when there is no traffic in the US 74 Express Lanes and access to the lanes is secured by the access gate system. The equipment would be accessed from a maintenance truck located in the lane to perform the required maintenance. Typically there would be two time slots of at least two hours in duration when the maintenance could take place (see Section 3.2.1.2 for further information).

The electronics supporting the tolling equipment will be located in the cabinets in the median and will require minimal maintenance. Most routine maintenance activities can be accomplished remotely. In the event emergency maintenance is required while the lanes are operational, the technician's vehicle could be safely parked on the shoulder with proper MOT and the technician could work on the equipment in the barrier protected median. It would be beneficial for the technician's vehicle be outfitted with a flashing arrow board or similar traffic control device.

Maintenance requirements should be based on Triangle Expressway RTCS contract standards, customized for the unique nature of the project. Response times may be relaxed somewhat because of:

- Lack of economies of scale for such a small project
- The narrow band of time full access is permitted to the US 74 Express Lanes, without closing the lanes
- Lack of strong project revenue component
- Building in greater redundancies into the RTCS

Customize Triangle Expressway RTCS maintenance requirements for this project.

Maintenance of the reversible gate system would be handled in a manner similar to the toll site maintenance. In the event of a catastrophic failure, lanes could be closed using the gate system on off-peak times or during the night to perform the repairs. The losses would be, at a maximum, 10 hours of lost toll revenue. This however is more desirable than three to five hours of losses during the rush hour periods. There is flexibility in the lane operation to perform the maintenance and repairs without drastic interruption of the lane operation.

5.3.5. Power

The project corridor has been surveyed for power service considerations. No unusual circumstances exist that would require mitigation.

5.4. Back Office Toll Collection Component

The BOS designed for the Triangle Expressway project, was created to meet all of the functional requirements to manage all North Carolina toll collection systems, and to serve as the universal processing system for ETC devices for the State. The Triangle Expressway final Detailed Design Document (DDD) dated February 6, 2015, for the BOS will be utilized as the base BOS document for the US 74 Express Lanes. The BOS DDD details software architecture, database, the video capture and enforcement system, self-service website and IVR, networks and communications, system interfaces, system security, and interoperability. It is envisioned that NCTA will negotiate an Extra Work Order with the BOS Contractor, as contemplated in BOS contract documents, for the required changes to the BOS necessary to accommodate the US 74 Express Lanes project in the existing BOS. An overview of the BOS as described in the DDD can be found in **Appendix E**.

5.4.1. System Upgrades to BOS Required to Support Project

The functional components of the Triangle Expressway BOS may require upgrades to incorporate the US 74 Express Lanes. These potential upgrades must be specifically addressed within the Extra Work Order process, assuming NCTA negotiates with the existing BOS provider, for technical information and a price proposal. The Extra Work Order process will require NCTA to specify:

- How the US 74 Express Lanes will operate
- If there will be any business policies specific to US 74
- What impact might there be with I-77 Express Lanes also requiring possible different business policies

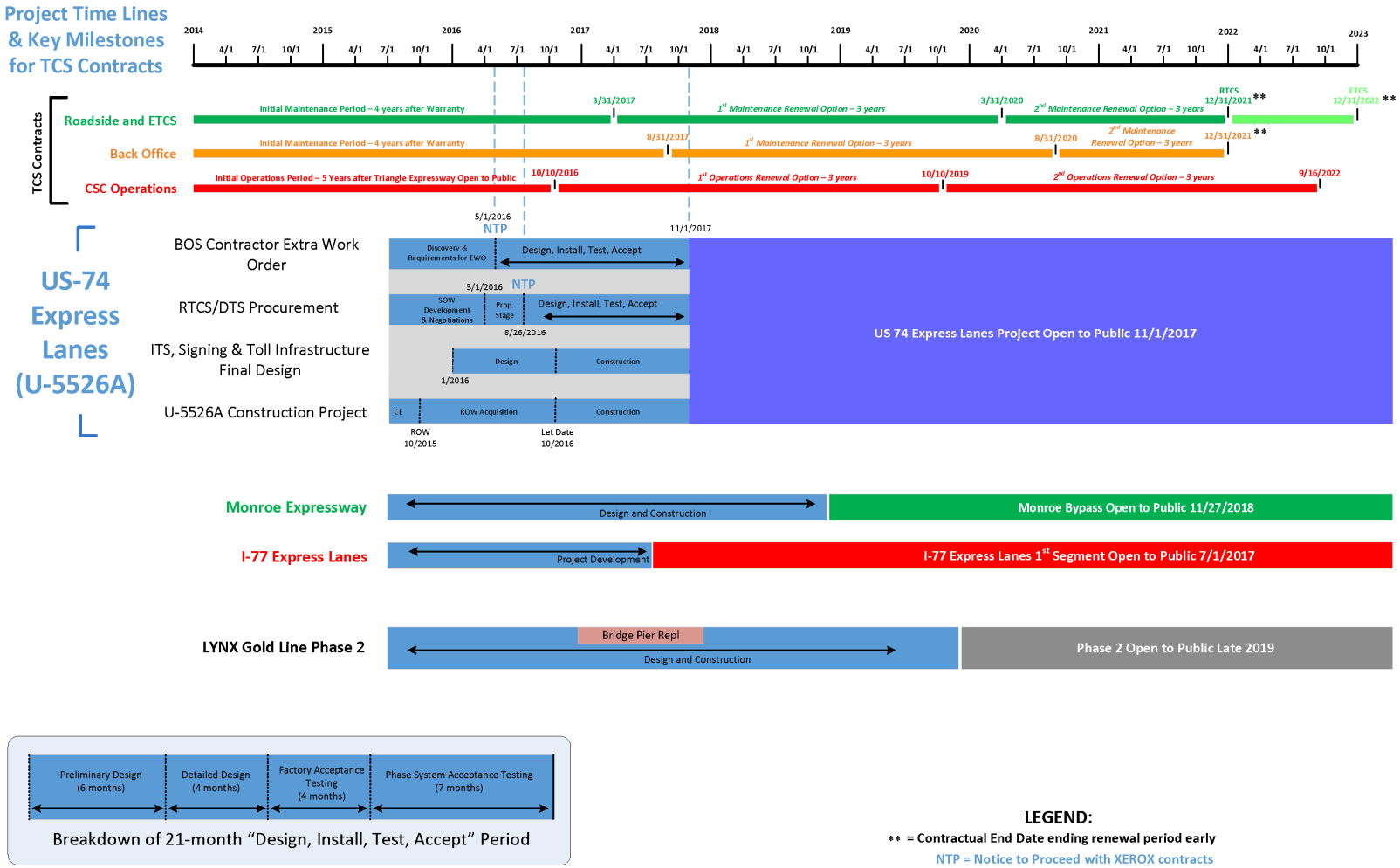
All possible BOS system impacts need to be addressed during the Extra Work Order process. Negotiating the Extra Work Order can take several months, especially when it is known that other toll facilities may be coming online within a short time period of US 74. Once a scope of work is agreed the development of the necessary BOS changes will follow a traditional course of system implementation:

- System General Design and Operations Plan
- System Hardware Design and Cut Sheets
- System Software Design
- System Network Evaluation
- System Test Program Design
- Factory Acceptance and Regression Test Plan
- Installation and Site Testing
- End to End Testing
- Implementation – Open to the Public

5.4.1.1. Contract Implementation Schedule

The following diagram **(Figure 7)** provides a high level look at the expected time frames for the Extra Work Order process and system implementation for the US 74 Express Lanes. This figure also includes timelines for other related projects listed in Section 1.4:

Figure 7. Contract Implementation Schedule



It is anticipated that it will take approximately six months to develop the scope of work for the US 74 BOS requirements coupled with successful negotiations with BOS Contractor for the required effort. Even though the diagram depicts a 24 month period for the design, installation, testing and acceptance of the BOS improvements, the goal would be to actually accomplish this within a maximum of 21 months. The three month period just prior to scheduled opening would be utilized for end-to-end transaction testing. This also assumes that the roadside system will be concurrently available.

Should BOS negotiations fail with BOS Contractor a much more complicated implementation process would have to be employed due to the additional burden of integrating a BOS processing that would carry NCTA into the future. In addition to the US 74 requirements for BOS processing is the added processing of I-77 Express Lanes currently scheduled to open 9 months after US 74.

BOS Extra Work Order planning needs to start immediately.

5.4.1.2. Transaction Processing/Revenue Collection

An ICD will be required by the RTCS integrator that defines the format and information that must be in the transaction to be processed by NC Quick Pass. The BOS DDD has a defined ICD for transactions being sent to the BOS for processing. This ICD is located in Appendix I of the BOS ICD. BOS operations will be performed through NCTA's established BOS to ensure economies of scale, established and proven system, compliance with state legislation, DMV agreements, and customer convenience. These are the same processes that are currently in place for Triangle Expressway transactions. The BOS Contractor has indicated that the ICD will need to be updated since I-77 will be transmitting trips and additional information will be necessary to receive a complete transaction.

The BOS currently supports two forms of revenue collection; pre-paid tolls through ETC accounts and post-paid tolls through a video billing process (Bill-by-Mail). NCTA's BOS can accommodate prepaid video accounts; however, currently this account option is not available to the general public per NCTA policy. US-74 Express Lanes will be required to accept current NC Quick Pass transponders (eGo Plus, eZGo Anywhere, and eZGo Anywhere Exterior). The BOS will also be able to process interoperable transactions stemming from all E-ZPass transponder types as well as Florida's SeGo tags. Additional protocols may also be needed in order to comply with interoperability requirements of MAP 21.

New customers signing up to utilize the US-74 Express Lanes will follow the same processes currently employed by the NC Quick Pass program. They may sign up through the website at www.ncquickpass.com; request an application through the web or via phone and mail in the application; or by stopping in at any store front location and completing an application.[2]

5.4.1.3. BOS Functionality

All of the existing features of the BOS will to some extent be affected by the addition of a new facility. With the addition of US 74 Express Lanes and I-77 HOT Lanes, the BOS will need to have the necessary functionality to not only process ETC and video transactions from these additional facilities but will also have to be able to accurately manage system requirements that are specific to each facility in order to provide quality customer service. The BOS will still debit and credit a customer's single account in the same manner as it does for Triangle Expressway transactions when transactions are received from US 74 and I-77. However, there will be requirements for separate reporting, by facility, which has not been tested.

The Request for Proposals for the Triangle Expressway Toll Collection Management System provided both notice and requirement specifications to BOS bidders that the BOS had to be flexible enough to add additional toll facilities with minimal changes to the underlying TCS. Within the concept of Express Lanes and HOT Lanes lies the possibility of transactions that are based upon travel through multiple toll zones that are combined into a "trip." The impact of a trip transaction on the BOS would probably be minimal if the Express Lane or HOT Lane facility builds the trip prior to sending it to the BOS as a single transaction with one toll due. If, however, the Express Lanes facilities sent multiple transactions that the BOS had to weave

[2] ConOps, AECOM, Page 39

together to create that same trip, the impact on the BOS would be substantial because that trip building software module has not been utilized not to mention there could be different trip building rules for each of the new facilities.

Additional possible impacts to the existing BOS functionality can be classified by the various modules that control the following:

5.4.1.3.1. Customer account management functionality

- Account types
- Enrollment
- Management
- Transponder fulfillment
- Transaction and payment processing
- Video Toll Invoicing
- Customer correspondence
- Reconciliation
- Walk-in account services
- IVR/Call center
- Non-payment escalation
- Account closing and refund processing

5.4.1.3.2. Finance/reciprocity management

The BOS currently supports a reconciliation process to ensure all transactions and associated revenues are properly accounted for. Such functions include:

- Financial and transaction reconciliation and audit
- Financial, transaction and operational reporting
- Reciprocity with all other organizations which NCTA has entered into an agreement

The BOS will have to have a reporting system that accounts for all transactions and provides financial reconciliation of all transactions and revenues for each North Carolina toll facility. Appropriate revenue, reconciliation variances, performance and operational data will be provided in reports that are complete and accurate to allow for the monitoring of operational and financial performance. Any additional report formats necessary for this project will be developed and approved during the design phase.[3]

5.4.1.3.3. Transponder inventory management

If there are unique characteristics for transponders being used in the Express Lanes or HOT Lanes environment, such as a transponder that can declare vehicle occupancy compliance, the inventory management system will have to be adjusted to handle distribution of the new transponder type.

5.4.1.3.4. NC Quick Pass Web site

In addition to changes in the BOS, the NC Quick Pass Web site will require modifications to accommodate the additional information required to provide the NCTA customer base with the appropriate tools to make decisions regarding use of the US 74 Express Lanes. Web modifications to the website and mobile web could be required as listed below[4]:

- Add general details on Express Lanes and their operations
- Updated maps specific to US 74 Express Lanes
- Include real time traveller information (speeds, travel times)
- Include current toll rates and moving average of historical toll rates throughout each day of the week
- US 74 Express Lanes incident location and status

[3] ConOps, AECOM, Page 40
[4] ConOps, AECOM, Page 41

5.4.1.3.5. Phone system and Interactive Voice Response

The IVR is a part of the BOS that supports customer service. The current IVR supports activities associated with the Triangle Expressway and has the capability of incorporating new projects. With the addition of US 74, the BOS processing requirements for the IVR will have to be modified to accommodate the unique content of calls requesting US 74 Express Lane information.

5.4.1.3.6. Image review

The process for image review should basically remain the same. Images will accompany US 74 video transactions and will follow the same processing rules currently in play with Triangle Expressway. The ICD between the roadside transactions and BOS should be sufficient to process video transactions. Other parts of the BOS will be affected, such as reporting image processing efficiencies for US 74, and should be addressed in the development of the BOS scope of work resulting from the additional tolled facility.

5.4.1.3.7. Video Toll Invoicing (Bill by Mail)

There should only be a minimal change to the Bill by Mail process. The process of obtaining vehicle ownership information will remain the same. There have been no legislative mandated changes to the video toll invoicing process for Express usage by a non-transponder identified vehicle. There will be some additional reporting requirements and impacts to the statement/invoicing processing that will have to be addressed in the scope of work development for the BOS.

5.4.1.3.8. Dynamic Tolling Software

Dynamic Tolling Software is discussed in detail in Section 5.2.4.

Further details on Extra Work Order requirements can be found in **Appendix E**.

Pursue Extra Work Order with NCTA BOS Contractor for Back Office System revisions including Dynamic Tolling Software.

5.5. NCDOT IT/EPMO Coordination and Compliance

The EPMO has the mission "To develop and implement standards and accountability measures that enable the State CIO's Office to fulfill its responsibilities for IT projects, programs and portfolios.

As detailed in **Appendix D,** the oversight of any project utilizing IT infrastructure, software development and/or computational systems are governed by the EPMO office of North Carolina. The keys to gaining approvals for a project such has US 74 are:

- Get approvals well in advance of implementation of any portion of the project
- Keep all personnel informed
- Stay within budget
- Complete the project on time
- Manage the project effectively
- Continue to coordinate with DOT IT on the communications design

A new and separate RTCS/ETC or BOS procurement would trigger a formal EPMO effort requiring development of the required documents and approval. In the case of an Extra Work Orders to the existing RTCS/ETC/BOS Contractors for US 74 Express Lanes, relatively minor changes would be required for the documents and much of the existing technical information would still be valid and therefore reduce the cost to NCTA to manage the EPMO oversight.

Training for the new EPMO project management tool (MS Project-based software) is needed for NCTA staff and consultants in order to fully plan for EPMO requirements and milestones. Following training, specific action items for the EPMO task will be identified.

Pursue modification of the existing IT/EPMO tracking project for Triangle Expressway, to apply to the US 74 Express Lanes RTCS, ETC and BOS efforts.

Obtain training for NCTA staff for new EPMO reporting software and procedures.

6. INTELLIGENT TRANSPORTATION SYSTEM

6.1. System Overview

The ITS system will consist of CCTV, MVDs and DMS devices. There will be 20 CCTV along the corridor for traffic management, verifying the toll rates, and confirming the closure of the US 74 Express Lanes during reversal. There will be six DMS to display the variable toll rates and there will be two on each approach to the corridor. There will be 35 MVDs along the corridor at approximately 1/3 mile spacing. The MVDs will be used exclusively for providing data to dynamic tolling algorithm and for other related toll reporting functions. Due to setbacks in some areas, it will take two MVDs to detect both directions of traffic. The ITS devices will be connected to and managed from the MRTMC.

6.2. Choice of Primary and Secondary TMC

The STOC has some flexibility to reallocate space for staff to operate the US 74 Express Lanes. The CSC does not currently have a monitor or video wall that would be needed to operate the Express Lanes. But most importantly, the option of operating the Express Lanes from the STOC or any other facility in Raleigh creates a potential single point of failure in the communications link between the project and the operations center. If the link fails, all control of the corridor devices and the dynamic tolling algorithm is lost. This link would also require a high bandwidth connection to transmit live video, still images and data.

Through discussions with CDOT and NCDOT staff, it was determined to operate the US 74 Express Lanes locally from the MRTMC. Local staff know the area and the corridor better, have the institutional knowledge, and can provide better response times to manage the operations. In addition, coordination with the MRTMC staff is essential. Further discussion concluded the Express Lanes operations staff should be collocated with the NCDOT staff at the MRTMC to provide better incident management coordination. Therefore, the MRTMC will be the primary control TMC.

However, NCTA (and NCTA operations staff) shall remain the ultimate decision-making authority, and have responsibility for US 74 Express Lanes operations and maintenance, due to their accountability to upper level NCDOT management for a revenue-generating project.

The existing control room would only support limited expansion of staff, but the adjoining conference room could provide space for additional Express Lanes operators. This space could be configured to view the existing video wall, or function with a “mini-video wall” consisting of large desk or wall-mounted monitors. Capital funds should be provided in U-5526A to create a workable control room space to manage the Express Lanes.

Further develop plans for control room space at the MRTMC for Express Lanes operations.

The combined staff would manage all aspects of the US 74 Express Lanes as follows:

- Monitoring traffic, including special events
- Responding to incidents
- Set the mode of the dynamic tolling pricing
- Opening, closing, and reversing of the US 74 Express Lanes
- Verify correct pricing on the DMS signs
- Monitor dynamic tolling algorithm
- Monitoring toll equipment status
- Schedule and perform equipment maintenance

Since this project is only the first of at least four toll projects in the Charlotte region projects on I-485, US 74 and the Monroe Expressway, the recommendations address only the first phase. At some point at longer term solution to the space needs of the MRTMC will have to be addressed.

The system design will allow remote access from the STOC through the network in Charlotte. This will provide the STOC secondary command and control through remote access.

6.3. Conceptual Network Configuration

The proposed conceptual network configuration is shown in **Figure 8.** In Charlotte, the Express Lanes system will include one existing network, three modified networks, and two new networks (all Ethernet 100Mb, 1Gb, or 10Gb networks) either at the MRTMC, at the project corridor, or between the two sites.

Existing NCDOT/CDOT Networks:

- CDOT/NCDOT CCTV network for general purpose lanes cameras

Modified NCDOT Networks:

- NCDOT network for traffic management DMS (modified for new locations)
- NCDOT admin network for all employees (new workstations and operators)
- MRTMC ITS network will be modified to accept digital images from US 74 Express Lane CCTV onto the video wall via a pair of firewalls

New US 74 Express Lanes Dedicated Networks:

- Express Lanes tolls network for in-lane equipment, ROCS/security cameras, tolling workstations, and supporting servers
- Express Lanes ITS network for CCTV, MVDs, Gate Control System, and toll rate DMS

In addition there will be new or modified leased long-haul networks between Charlotte and Raleigh.

New US 74 Express Lanes Dedicated Communications Pipes:

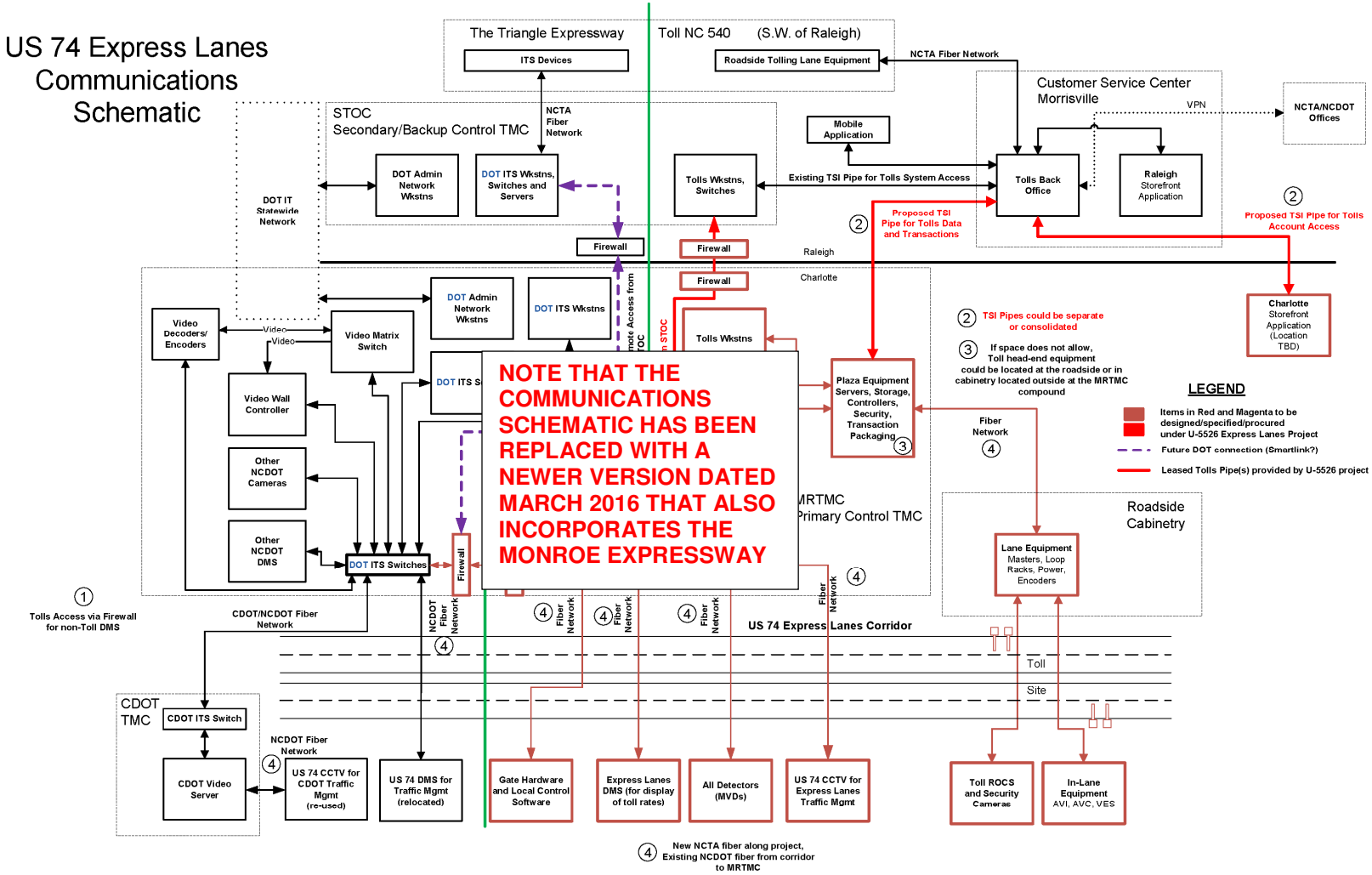
- From the MRTMC (or other secure facility) to the CSC/STOC in Raleigh, new tolls pipe for tolls transaction data and remote access
- From the MRTMC to the STOC in Raleigh, new pipe for secondary control of ITS devices and gate control system
- From the CSC to Charlotte storefront retail facility, new tolls pipe for BOS business systems

Modified NCDOT statewide network:

- From the MRTMC to the STOC for secondary control of non-Express Lane devices (DMS, CCTV)

During the operation of the US 74 Express Lanes the primary control of the Express Lanes devices on US 74 will reside with the Express Lane operator(s), otherwise they will reside with the local ITS operators. Secondary command and control will be possible from the STOC.

Figure 8. ITS and Tolls Communications Schematic



6.4. Telecommunication/Broadband Systems

If the video images of the proposed 20 CCTV cameras for the project are transmitted to the STOC for secondary command and control, that would require a 20 megabits/second connection based upon a streaming HD video resolution. If the resolution is reduced to standard definition, it would reduce the required connection to 5 megabits/second. That bandwidth could be significantly reduced if all 20 CCTV do not need to be viewed at the same time. Discussions with the NCTA TMC Manager suggest that bandwidth to support four simultaneous videos would be sufficient.

The NCDOT network connection from Raleigh to the MRTMC is not adequate for CCTV video sharing with the STOC. Since the MRTMC will be the primary control TMC, the need to stream large amounts of video is greatly reduced. If the STOC needs camera control to pan, tilt and zoom the cameras, then a high bandwidth dedicated leased connection would have to be leased until a NCDOT fiber-optic cable link could be completed.

From the MRTMC along I-277 to the west end of the project the 72-fiber-optic cable is intact. CDOT is allocated 24 strands of the cable. Very few of the NCDOT strands have been connected to operate the DMS and MVDs, therefore amble spare fiber is available running from the corridor directly to the MRTMC. The only work to utilize the cable is to install fiber-optic jumpers in the cabinet-mounted patch panel at 11th and Davidson Streets.

Since the MRTMC is proposed as the primary TMC for traffic management, it would then be logical to route all communications to the MRTMC where the video would be routed to the video wall through the existing Pelco video switch through firewalls.

Since the CCTV and MVDs will be used by the ITS and US 74 Express Lanes system, it would be more cost effective to make the data exchange between the roadside devices and the two systems locally to minimize large leased bandwidth communications costs. Since there will be soon be space at the MRTMC, it is recommended to locate the servers and related communications equipment in the MRTMC.

Since the proposed CCTV will be digital video the MRTMC can receive the video and decode it directly from the roadside.

There will be a local retail facility in Charlotte to enroll customers and sell or replace transponders. The existing Raleigh retail facility will also be able to sell transponders for use in Charlotte. Communications requirements to this facility (as well as the other tolls-related pipes - solid **RED** lines in **Figure 8**) will need to be further investigated in order to accurately budget for operations and maintenance cost planning.

Explore detailed bandwidth requirements to size tolls pipes from Charlotte to Raleigh.

6.5. CCTV System

It is proposed that additional cameras (shown in **ORANGE** on the ITS Concept) be installed and dedicated to monitoring the US 74 Express Lanes. These cameras would be installed on the existing camera poles and share the same cabinets as the existing cameras. New cameras and poles will be placed to view the faces of DMS at each of the three ingress points (to verify correct information is displayed regarding pricing and Express Lane closure). All cameras would be connected through the NCDOT fiber-optic network to the MRTMC. The following bullets summarize the new CCTV camera network.

- New dedicated cameras, collocated with existing cameras (no new cabinets or poles): 9
- New camera locations on US 74 and Albemarle Road including cabinets and poles, east of existing coverage: 7
- New camera locations on US 74 and I-277 including cabinets and poles, west of existing coverage: 4

- Total new CCTV cameras: 20

It is recommended that all cameras use all-digital compression and networking equipment to minimize the required bandwidth between the STOC and the MRTMC.

6.6. Dynamic Message Signs

Through discussions with NCDOT, it was agreed the DMS on Albemarle Road is not well utilized and could be relocated given the sign spacing needed to accommodate advance Express Lane signage on Albemarle Road. It is recommended that this sign be relocated eastbound on US 74 near Westover Drive to provide incident management information for either the Express Lanes or general purpose lanes. The US 74 westbound sign near Wallace Lane will be relocated to a new sign structure further east to accommodate sign spacing needed for the Express Lane approach signing. Subject to a structural analysis, both existing DMS sign structures will be used for Express Lane signing.

The new DMS signs dedicated to the US 74 Express Lanes (shown in **ORANGE** on the ITS Concept) are located in accordance with the conceptual signing plan for the project.

Since the DMS for the US 74 Express Lanes system will be display graphics and toll information, they must comply with MUTCD for colors and message content. The spacing of the pixels in the sign face have an impact on driver acuity. A tighter spacing provides a sharper text or graphic message. A sharper, higher resolution message improves the driver's ability to comprehend the message. Full matrix signs that display graphics typically are available in 20, 34, and 66mm spacing. 66 mm spacing is inadequate for the display of graphics. The 20 and 34 mm spacing provides substantially better resolution but the 20 mm is approximately 25% more expensive. It is recommended that 34 mm DMS be used.

6.7. Detection System

Based upon experience of other Express Lane implementations, the recommended vehicle detector requirements are:

- Spacing of 1/3 to 1/2 mile to monitor traffic along the US 74 general purpose and Express Lanes;
- Use of non-invasive "side-fire" microwave vehicle detectors capable of collecting traffic volumes, speeds, and classification across multiple directions of travel;
- Connected via the fiber-optic network for continuous reporting of data to support the dynamic tolling algorithm used by the tolling system;
- Directional volume data for quarterly traffic reports and comparison to the toll system traffic data; and
- Speed data for external and internal congestion/speed maps and traveller information.

Several detector vendors were consulted and they provided guidance on the setback and mounting height requirements to detect both directions of travel. The ITS Concept reflects the more conservative requirements of the vendors.

Due to their age, the existing detectors do not have Ethernet communications capability and the more advanced radar that would support higher data transmission speeds and monitoring capability and detection capabilities. It is recommended the existing detectors be replaced due to their age (approximately 8 years old) and limited functionality. To the extent possible, the existing detector poles and supporting infrastructure will be used. If camera poles and sign structure uprights are in suitable locations, they will be used to mount the detectors.

The proposed detection system (all shown in **ORANGE** on the ITS Concept) will consist of:

- Replace existing detectors on US 74 and Albemarle Road: 12
- New detector locations on US 74 west of Albemarle Road: 11
- New detector locations on US 74 east of Albemarle Road: 14

- New detector locations on Albemarle Road: 2
- Total new detectors: 39

Similar to that deployed for Triangle Expressway, the US 74 Express Lanes detection system should include a Speed Map that displays current speeds segment by segment, for both the Express Lanes and the general purpose lanes. Such a map can be deployed on the NCTA website as well as used internally to detect incidents.

6.7.1. Role of 3rd Party Traffic Data

The collection and distribution of traffic data by 3rd party organizations is available and is used by many commercial entities such as TV stations, websites, commercial vehicles operations, etc. Considerations for the use of this data by the dynamic tolling system included:

- Does the 3rd party provider have the proper resolution needed for the calculations?
- Does the 3rd part provider differentiate the information by lanes?
- Does the provider guarantee data accurate enough for the calculations of tolls?
- Can the 3rd party data be controlled by Key Performance Indicators (KPIs) and liquidated damages (LDs) that will mandate performance so loss of control or data streams are manageable?

The answer to each of these questions is “no”.

When INRIX was queried with the above questions, the initial response was that they are unable to separate data by lanes. This feature is discussed for future enhancements but there is no anticipated date for the implementation. In addition, INRIX data provided for a newly opened road will not be available on opening day and may not be available for months. This prohibits the use of such services in their current performance models.

The recommendation in general is not to utilize 3rd party traffic data but this may be re-considered if an agreement is available with a Memorandum of Use that gives high priority access to the data, guaranteed calibration and KPIs and LDs for non-performance.

6.8. Power

The project corridor has been surveyed for power service considerations. No unusual circumstances exist that would require mitigation. However, for certain detector sites, the project may want to employ solar power as a low-cost alternative for power in hard-to-reach sites. A pictorial example of such a deployment can be seen in the ITS Concept, sheet 6.

6.9. ITS Maintenance

The ITS components are part of the toll system and therefore will be monitored and have issues reported by the Maintenance Online Management System (MOMS). In order to manage the corridor, there are traffic monitoring stations and CCTV cameras along the US 74 closed portion. The current layout can support the operation with a single point of failure until repair is able to be done.

For the Triangle Expressway, a performance-based ITS maintenance change order was negotiated with RTCS maintenance provider. This decision was motivated by the need to:

- Transfer risk from NCTA
- Define response times and penalties for non-performance
- Keep devices such as DMS and MVDs at high level of performance due to connection to revenue collection

Since maintenance is performed on the off-peak times concurrent with toll and gate system maintenance, it is most cost efficient to have the maintainer of the toll system handle all toll related ITS components. This is

also necessary because the Key Performance Indicators for the US 74 Express Lanes will be tied to the traffic data, placement of the toll rates on the DMSs and visually verifying that the toll system is operationally correct and functioning.

ITS device maintenance, including fiber-optic communications maintenance, should therefore be provided by the same provider as the RTCS maintenance. This will include the adherence to response and repair times in the contract. The few remaining ITS devices on the corridor NOT dedicated to the US 74 Express Lanes (the non-Express Lanes cameras, and the traffic management DMS) can either remain under existing service agreements or be folded into the Express Lanes maintenance package.

Pursue maintenance contract that utilizes same provider for ITS maintenance as for RTCS maintenance.

6.9.1. Traffic Control

For existing and proposed devices on the outside of the roadway, maintenance can be accomplished within NCDOT and the City's lane closure restrictions.

The design of the reversible US 74 Express Lanes section does not provide for maintenance vehicles to park on a full shoulder. Therefore, any maintenance to the field devices in the reversible lane section will occur during off-peak hours when the Express Lanes are not operating. For the Express Lanes east of Albemarle Road, there is the opportunity for a maintenance vehicle to park in the closed Express Lane and provide limited maintenance not over the operating Express Lane. If any emergency repair is required, the Express Lanes will have to be shut down. NCTA will make the operational decision whether such an action is warranted.

6.10. NCDOT IT/EPMO Coordination and Compliance

With the interaction of the toll systems with the MRTMC, STOC and the CSC, State IT and compliance is mandated. This will require constant coordination with the State IT and EPMO offices. In order not to miss installation and completion, proactive project management must be used to ensure that the proper people in the state agencies are properly briefed and that the approving persons are informed of the schedule and priorities. A new standalone IT project would be a time consuming and costly effort.

After discussion with DOT IT and EPMO, it was determined that the best approach was to qualify the ITS as an alteration (also known as a "task') to an existing IT project (the Triangle Expressway) and therefore streamline the IT coordination and compliance.

The ITS shall also adhere to the guidelines outlined in the NCDOT Intelligent Transportation System Configuration Management Plan.

Continue to coordinate with and comply with NCDOT IT/EPMO requirements.

7. ROADWAY MANAGEMENT

The term Roadway Management in its broadest sense includes the overall process of managing and overseeing the wide range of functions, duties, responsibilities and activities essential for the safe, effective and financially responsible design, development, operation and maintenance of a roadway facility such as the US 74 Express Lanes.

These functions, which are addressed in greater detail below, include roadway operations, traffic management, toll revenue collection operations, general maintenance of the roadway as well as the tolling and ITS systems and related infrastructure. It also includes oversight and management of the critical financial and reporting functions designed to assure the complete and accurate collection and accounting of all toll traffic revenues and transactions and their proper recording and reporting for auditing, budgeting and financial planning purposes.

7.1. Tolling and Roadway Operations

The RTCS is the primary technology system that supports the tolling and roadway operations of the US 74 Express Lanes project. The RTCS will include complete AET functionality for the Express Lanes and toll zones, including in-lane and gantry-mounted hardware and software subsystems for ETC; vehicle identification, separation and camera triggering equipment; and automatic license plate recognition subsystems with their video processing and OCR capabilities.

Transaction and toll system maintenance data generated in the US 74 Express Lanes will be sent to a remote toll host computer for processing. Maintenance data will be monitored by the MOMS that will report and provide alerts when there are system issues, such as equipment malfunctions or failures.

The Traffic Management System (TMS) component of the RTCS (which will be integrated with the existing TMC) will support the following: traffic detection; measurement of traffic volumes and Levels of Service (LOS) in the Express and general purpose Lanes; reversible lane operations; traffic and incident management; will provide inputs to the back office for the determination of dynamic pricing; and support system monitoring.

The TMS and subsystems will support these essential roadway operation functions utilizing a number of technologies including:

- Roadway overview cameras (ROCS) and site security CCTV
- Automated Incident Detection (AID) video-based detection
- Non-intrusive roadway sensors
- Tolling point vehicle detection readers and associated equipment
- Dynamic message signs
- Lane control signals
- Automated barrier gates
- Variable speed limit signs
- Maintenance management system (such as MOMS)

7.2. Operations Staffing

It is anticipated that a pair of dedicated US 74 Express Lanes TMC operators will be required to manage the Express Lanes, working in overlapping shifts. In periods of low activity it may be possible for these operators to support emergency non-Express Lanes needs for the local traffic network. Likewise, regular MRTMC operators could be called upon for Express Lanes-related assistance in a crisis or in the case of sick or vacationing Express Lanes operators. Training plans and operating procedures will be developed to account for the necessary staffing adjustments during such situations.

Budget for two full-time Express Lanes TMC operators in project planning.

Supervision of Express Lane operators would be supplied by existing NCTA Operations staff. Existing NCTA Standard Operating Procedures for TMC operators will be updated and customized for Express Lanes operations, gate control operations, and for interactions with non-Express Lanes operators.

Update NCTA Standard Operating Procedures with project-specific details.

7.3. Toll Rate Adjustment Procedures

Following the recommendations for Toll Rate Adjustments of the FHWA would bring a consistency from facility to facility. Criteria is defined for the minimum traffic flows based on geometry and use. These variables are applied to algorithms that are utilized to compute the toll rates based on all applicable factors.

Based on a criteria of maintaining a minimum traffic flow speed of 45 mph 90 percent of the time, the corresponding Level of Service (LOS) on US 74 Express Lanes would be "D" or better (see Table 3 in **Appendix C**). The determination of the Level of Service is based upon the Traffic Density (TD), which affects both volume and speed of traffic. The traffic volume is defined as the number of vehicles passing a certain point within an established time period. The US 74 Express Lanes traffic volume must be combined with the average speed of the vehicles because a low vehicle count alone could indicate either low congestion or when the road is heavily congested with slow moving traffic. See **Appendix C** for more details.

Operating policies need to be developed to define the basic rules for toll adjustments over all NCTA Express Lanes facilities. Such policies will be incorporated into the Express Lanes Standard Operating Procedures manual. This is not addressed in this document but must be addressed as the project progresses to the next phase.

Devise operating policies to develop the basic rules for toll adjustments over all NCTA facilities.

7.4. Reversible Lane Operations

The US 74 Express Lanes will be open during AM Peak and PM Peak traffic periods with extended morning and afternoon operating hours. Operating hours may also be adjusted to accommodate sporting events and other special activities. The reversible lane segment located on its western end (and therefore the entire Express Lanes) will be closed for reversing operations and facility maintenance a minimum of twice per day.

A gate control system, previously described, will be installed to prevent motorists from unintentionally entering the reversible Express Lane from the wrong direction. Gates will be used to close off Express Lane access ramps that would flow opposite the prevailing direction of traffic. This would occur when the direction of flow in the US 74 Express Lanes is reversed to accommodate the traffic flow heading west during the AM Peak Period and heading east during the PM Peak Period.

7.4.1. Reversible Lane Hours of Operation

The US 74 Express Lanes (including the reversible lane section) will be operated only during the morning and afternoon peak periods and will be closed to all traffic during certain hours, as described below:

Weekdays		
Open Westbound	02:00am to 12:00pm	Inbound rush hour
Closed	12:00pm to 02:00pm	Mid-day Traffic reversing & maintenance
Open Eastbound	02:00pm to 12:00am	Outbound rush hour
Closed	12:00am to 02:00am	Night Traffic reversing & maintenance
Saturdays & Sunday		
<To be determined>		

These preliminary hours are based on traffic data collected as a part of the "US 74 Managed Lanes Final Level 1 Traffic and Revenue Study". The same study states that "US 74 does not experience heavy weekend congestion." Further study is needed to determine if US 74 weekend traffic would benefit from weekend operations in the Express Lanes.

Study further the need for Express Lanes operating hours during the weekend.

7.4.2. Reversible Lane Management

Automated barrier gates, dynamic signs, and static signs will be used to control, monitor and manage the reversible lane operations. The US 74 Express Lanes operator at the MRTMC shall be able to remotely control automated reversible lane equipment (e.g. gates) and driver information systems (e.g. signs, lane control signals, etc.) that control access and egress to reversible lanes as well as traffic in the reversible lane.

7.4.3. Switchover / Reversing Direction of Traffic Flow

The process of switchover involves a combination of automated gate control software managed by TMC operators and CCTV monitoring prior to switchover. The switchover is performed by the TMC and would occur following sequential gate closures along the directional facility (beginning at the east end for westbound traffic, beginning at the west end for eastbound traffic). These reversible lane management operations shall include physical on-site "sweep" operations by roadway field staff during directional changes to verify that no vehicles are entering, nor are there any vehicles remaining in the reversible lanes. Once the road is verified as "clear" to TMC staff, the direction of traffic is reversed. The switchover should typically take less than one hour.

7.4.4. Gate Control System and Reversible Lane

The Gate Control System is considered to be the most critical ITS subsystem from both a safety and a maintenance standpoint. The GCS will control both the gates for the US 74 reversible lane and the DMS that alert drivers whether the reversible lane is open, closed or closing, and thus must be fully fault-tolerant, with no downtime. Any malfunctions or improper operations will require immediate response from maintenance personnel.

7.5. Incident Detection, Monitoring and Surveillance (TMC Focused)

The MRTMC facility will be used to support and operate the US 74 Express Lanes project. In the future, after the statewide advanced traffic management system software (NC SmartLink) is available, and statewide communications provide center-to-center connectivity, the STOC in Raleigh should be considered as the hub for operating dynamic pricing statewide while relying on the local TMC to continue to provide incident management functions, and reversible lane operations if applicable.

Re-evaluate site of dynamic pricing hub if and when NC SmartLink comes online.

7.5.1. Incident Management

Incident management includes a series of activities, which are carried out by operators in the TMC working in accordance with a variety of first responder agencies and organizations. An effective incident management program should detect, respond, verify, clear, and communicate information about an incident quickly to return a facility to its normal operation.

An accident or incident must first be detected for a response to be initiated. The sooner an incident can be detected and the proper responses initiated, the sooner the problem can be cleared and the facility returned to normal.

Detection capability is provided along the roadway corridor to monitor the flow of traffic on a continuous basis. Data collected from various sources is analyzed to determine speed, volume, density, etc. Anomalies detected in the normally expected traffic flow patterns, indicate that an incident has likely occurred. Such anomalies then trigger an alert to the TMC.

Once the US 74 Express Lanes operators in the MRTMC are alerted, the incident will be observed and assessed by staff in the TMC and/or roadside operations field staff. Once the incident is assessed, the incident management plan is implemented and appropriate response is made. The appropriate response may involve any number of measures including dispatching of emergency personnel (ambulance, fire, police, etc.), providing information to motorists, and/or dispatching crews to clear the incident, in order that that safe, efficient traffic flow can be restored.

It is important to note that some of these incident management activities may be performed concurrently. For example, traveller information is continuously updated through the duration of an incident while other activities, such as clearance, are taking place.

MRTMC operators not dedicated to US 74 Express Lanes will serve as additional back-up if incidents are of such magnitude that additional staff is required. Likewise, in times of low intensity operations, Express Lanes operators can support NCDOT.

7.5.2. Detection

Detection refers to the ability to identify that an incident has occurred and to obtain accurate information on the location, nature, and scope of the problem. Detection capability will be provided along the roadway corridor to monitor the flow of traffic on a continuous basis. Data will be collected from various sources (e.g. roadside detector devices, surveillance systems, roadway field staff, etc.) for analysis to determine speed, volume, density, etc.

Incident detection on US 74 can be performed using a wide variety of methods, technologies and techniques including:

- Automated roadside detector devices
  - NCTA detector Speed Map
- Roadway surveillance devices
  - ITS (NCDOT and CDOT) CCTV roadway surveillance cameras
  - ROCS tolling point surveillance cameras
- Roadside field observers
  - Motorist calls from cell phones
  - NCDOT State Farm IMAP (phone, two-way radio)
  - Charlotte Metropolitan Police Department (CMPD), Fire and Rescue (scanner)
  - NC State Highway Patrol (phone, scanner, CAD integration)
  - Mecklenburg County Fire and Rescue (scanner)
  - Media (phone)

7.5.3. Verification

Verification involves confirming that an incident has occurred, determining its exact location, and obtaining as many relevant details about the incident as possible, and assessing the scope and severity of the incident. Verification includes gathering enough information to dispatch the proper initial response. Verification is conducted using the following activities:

- ITS CCTV roadway surveillance cameras viewed by US 74 Express Lanes operators at the MRTMC
- ROCS tolling point surveillance cameras

- Field personnel (e.g., police and responder vehicles) dispatched to the incident site

7.5.4. Response

Response includes dispatching the appropriate personnel and equipment, and activating the appropriate communication links and motorist information media as soon as there is reasonable certainty that an incident is present. Operators at the TMC usually lead this coordination. A listing of potential agencies for TMC operators to interact with relative to US 74 activities includes:

- NCTA Operations staff
- Charlotte Metropolitan Police Department (CMPD)
- Charlotte Fire Department (CFD)
- North Carolina State Highway Patrol
- Statewide Transportation Operations Center (STOC) in Raleigh
- NCDOT State Farm IMAP
- NCDOT Management
- NCDOT Public Affairs Office
- NCDOT Division 10
- City of Charlotte (CDOT, CATS)

7.6. Traffic Incident Management (Roadway-Focused)

7.6.1. Incident Site Management

Site management is the process of effectively coordinating and managing on-scene resources. The foremost objective is ensuring the safety of response personnel, incident victims, and other motorists. Command at the site typically follows the following hierarchy: (1) Fire/EMS, (2) State Police, and (3) the Department of Transportation. Several measures are taken to ensure safety. Responders take measures to protect themselves, their counterparts, incident victims, and other motorists. These measures are listed below:

- Responders implement Quick Clearance Strategies to move vehicles out of the traveling lanes and onto the shoulders.
- Responders park their vehicles directly behind the incident to provide a buffer between the incident and approaching traffic. Freeway safety patrol vehicles are often equipped with lights, DMS's (with arrows or message signs), and cones.
- Police and responder personnel work with the other emergency responders to minimize the number of lanes closed.

7.6.2. Traffic Management

Traffic management is the application of traffic control measures in areas affected by the incident. Traffic management occurs both at the incident site and at the TMC. On-site responders are responsible for the incident scene while the TMC looks at the regional view.

The TMC is responsible for determining the impact that the incident has on the region and react accordingly. TMC operators would activate the following types of devices to perform traffic management in US 74 project area:

- CCTV Cameras – TMC operators proactively monitor cameras for motorist assistance, accidents, traffic congestion, incident confirmation and clearance, and any other occurrence affecting the roadway system.
- DMS – TMC operators update the closest upstream DMS to the incident providing the type of incident, location of the incident, number of lanes affected, and suggested alternate routes. Travel Time information is posted on selected DMS signs as default message until higher priority information is posted by the operators.

- TMC Updates – TMC operators enter data for all incidents, construction schedules, special events, weather, and other declared events.

7.6.3. Clearance

Clearance is the process of removing wreckage, debris, or any other element that disrupts the normal flow of traffic and restoring the roadway capacity to its pre-incident condition. The North Carolina "Quick Clearance" law focuses on getting vehicles out of the roadway. It states that if law enforcement and NCDOT agree that a vehicle and its cargo pose a safety concern, they can move it by any means necessary without facing any liability. Traffic control and site management are also important elements of this process. The critical nature of restoring traffic flow in blocked or restricted Express Lanes requires that the roles and responsibilities of personnel from the various local agencies should be established to allow for the safe, efficient, and coordinated management of an accident or an incident site. Memoranda of Understanding (MOUs) may need to be negotiated between NCDOT, NCTA and local first responders.

Negotiate (MOUs) between NCDOT, NCTA and local first responders customized to Express Lane operations.

7.6.4. Communication

This element of an incident management program focuses on communicating information on the status of the Express Lane and freeway facilities to other agencies and the motoring public. A variety of techniques and technologies will be used to provide current or real-time information to Express Lane users, motorists in the general-purpose lanes, and other agencies. These include Express Lane DMS signs, traffic management DMS signs, NC Quick Pass website alerts, etc. This step is important to provide customers with information on major problems and significant delays on a facility, as well as on alternate routes that they may desire to take.

7.6.5. IMAP

Several factors suggest the need for a strong IMAP program on US 74 Express Lanes:

- Desire for positive public perception of a new tolling initiative
- Urgency to keep speeds on the Express Lanes above 45mph
- Complications arising for the separation of the Express Lanes from the general purpose lanes, and the possible need for long detours to assist motorists

After consultations with Division 10 ITS/IMAP representatives, it is recommended that a dedicated IMAP patrol serve the US 74 corridor, paid for by the project. Such a patrol would need two overlapping shifts to cover the two peak hour periods. Should it not be financially feasible to have a dedicated patrol for the corridor, the Division is open to the idea a “shared” patrol that might cover the project corridor plus some additional important and connected DOT freeway, such as I-277 or I-485. In the case this option is explored, NCTA would cover expenses in whatever proportion is appropriate given the nature of the route. Current agreements between NCTA and NCDOT regarding the Triangle Expressway IMAP strategy provide a template for this arrangement.

Plan for and budget for a dedicated IMAP patrol of two shifts for the corridor.

It is assumed that such patrol would be part of the State Farm-sponsored program. However details need to be explored regarding who pays for certain expenses, like “wrapping” the vehicle in the State Farm color scheme.

7.7. Enforcement

Assuming that HOT-3+ vehicles use the US 74 Express Lanes by mounting a declarable transponder, the primary enforcement duty for the Express Lanes will be enforcing the proper use of this transponder. Enforcement of vehicle occupancy requirements is accomplished through manual observation by police in the field patrolling the facility, as technology to automatically verify vehicle occupancy is still experimental. The RTCS will need to feature a technology to display to the enforcement vehicle the HOV-3+ status of subject vehicles.

Other enforcement activities include:

- Vehicle class (i.e., looking for trucks, assuming trucks are not allowed to use the Express Lanes)
- Vehicles illegally crossing in and out of the Express Lanes to avoid tolls
- Speeding and safety violations

Planning for the US 74 Express Lanes should include early involvement of the appropriate enforcement agencies. If the Express Lane facility will pass through several jurisdictions where each may take an active investigative and enforcement role, then planning should include early agreements to establish response and enforcement protocols. If only one police agency is involved, the transportation agency should request that a liaison be assigned to ensure continuity of input during the planning process.

This early involvement can be invaluable for resolving design issues for enforcement locations, investigation sites, and enforceable signing. The traveling public will also want information on how the US 74 Express Lanes will be enforced. Project sponsors should emphasize that enforcement usually relies on a combination of automated systems to verify ETC transactions and visual inspections to enforce moving violations and axle violations. All project stakeholders should coordinate early on with enforcement agencies as well as the local judicial system to agree upon enforcement strategies and policies and the degree to which state and local law allow these processes to be automated. A lack of upfront coordination could lead to misinformation and changes that could be detrimental to public support.

Plan for and coordinate enforcement strategies, define responsible parties, and to ensure public awareness of such policies.

As on the Triangle Expressway, it is anticipated that cost of law enforcement for the US 74 Express Lanes will be tracked as an integral part of the separate financial reporting for the project. Agreements are already in place for the Triangle Expressway with the State Highway Patrol and can be expanded to utilize State Highway Patrol for enforcement on the US-74 Express Lanes. However, initially discussions with CMPD suggest that they will continue primary enforcement responsibilities on US 74.

Further pursue discussions with CMPD on enforcement responsibilities/limitations, and technology developments for HOV enforcement.

Specialized enforcement areas near the tolling point, where officers could look for HOV violations, are under consideration by the U-5526A consultant and will be updated when information is available.

7.8. Special Events & Emergency Management

Toll-paying customers expect an enhanced level of service at all times, but especially during recurring congestion (peak hours) and during non-recurring congestion such as incidents and special events. Special events may sporting events such Carolina Panthers games, Charlotte Hornets games, Charlotte Checkers games, ACC Football Championships, NASCAR races, etc. Hence, an effective incident management plan for the US 74 Express Lanes provides travel time reliability and an enhanced level of service for traffic safety and mobility. Integrating a succinct incident management process and continual monitoring and evaluation of travel time are key proactive measures for the success of Express Lanes.

In the case of a catastrophic event, natural or man-made, the US 74 Express Lanes would be operated in accordance with the Traffic/Incident Management Operating Plan (to be developed). In such situations the Express Lanes may be opened to all motorists and the toll operator would permit free passage. NCTA Operations staff would make the determination of whether to waive tolls in accordance with Department policy. Direction of operation would be determined based on the nature of the event. Catastrophic events may include the following: hurricanes, terrorist events, massive chemical incidents, extreme mass flooding as well as others. Law enforcement would provide guidance and direction to the general public on using the US 74 Express Lanes. The system would still collect operational and traffic data. As such, toll transactions occurring during times when tolls are waived would be processed in the back office and toll transaction adjustments made accordingly.

Disaster planning should specifically address "worst case" scenarios where on or more incidents occur within the reversible lane section.

Establish protocols and operating plans for US 74 Express Lanes during special events and emergency events. Ensure that gate control strategies are fully developed as a part of this effort.

7.9. Roadway Maintenance

After consulting with NCDOT Division 10 authorities, it is proposed that NCDOT undertake and have overall responsibility for the routine maintenance of the US 74 Express Lanes, general purpose lanes and shoulders to ensure the facility's safe, continuous and efficient operation.

This responsibility would include:

- Approval of the routine maintenance activities and sub-contracts
- Interface and support efficient operations with the US 74 Express Lanes traffic management center
- Relationship management with all key stakeholders

NCDOT would perform the following maintenance activities through a combination of in-house and sub-contracted resources or suppliers. Sub-contracted services may include:

- Snow and ice removal
- Environmental monitoring and response
- Maintenance and replacement of signs
- Reversible gate maintenance (not including electronics or software)
- Line marking, delineators and Express Lane separator/pylon replacements
- Incident response and clean-up
- Debris removal and roadside litter
- Road sweeping
- Barrier wall, guardrail and attenuator repair
- Mowing and landscape maintenance
- Highway lighting maintenance in controlled access areas
- Graffiti removal
- Pavement condition assessments
- Specialist engineering services

These services will be conducted in a manner that is seamless to the customers in both the US 74 Express Lanes and general purpose lanes with all maintenance activities coordinated and managed as an integrated activity with the US 74 Express Lane TMC and relevant stakeholders.

Pursue plans for NCDOT Division 10 to provide routine roadway maintenance for the corridor, including the Express Lanes.

7.9.1. Roadway Maintenance Performance Standards

Established standards for roadway maintenance provide a clear set of goals that would be used to guide and monitor the maintenance process of the US 74 Express Lanes to ensure that the facility meets customer expectations as well as considerations unique to it.

It is proposed that the roadway maintenance standards similar to those that were developed for the North Carolina Turnpike Authority's (NCTA) Triangle Expressway through a collaborative effort by NCTA Managers, NCDOT maintenance staff and consultants be adopted and used by NCDOT Division 10 in performing routine maintenance on the US 74 Express Lanes (but not the general purpose lanes). This program is called the Maintenance Rating Program (MRP) and details follow.

7.9.1.1. Triangle Expressway Maintenance Rating Program

This process consists of quarterly inspections that are conducted during the months of February, May, August, and November to account for dynamic changes in assets during each season. A randomly selected sample of maintenance characteristics is evaluated each quarterly inspection according to the criteria developed by the NCTA performance standards and is assigned either a Pass or Fail rating. After the inspections are completed, the number of passing and failing characteristics is totalled and a maintenance rating score from 1 to 100 is assigned to each characteristic. This score represents the percentage of assets that are currently meeting the condition standards. The NCTA's overall target rating score is 90, with the target rating score for elements being at or above 85 and the target score for characteristics being at or above 80.

Arrangements have been made with NCDOT Division 5 to provide maintenance to the Triangle Expressway. Results from each MRP inspection are submitted each quarter to the NCDOT Division 5 Freeway Program Manager. Based on these results and the recommendations provided in the quarterly maintenance rating reports the freeway program manager is able to determine and manage the maintenance services provided to the Triangle Expressway.

Create a customized MRP for the US 74 Express Lanes.

7.9.2. GIS Documentation

NCTA possesses a Geographic Information System (GIS) that serves as a coordinate-correct repository for the location and other details of various elements of the roadway system, including power meters, light poles, ITS poles and devices, tolling equipment, conduit, etc.

As as-built plans are received by the various contractor, the GIS system will be expanded to include the US 74 corridor, using standards and symbology already created.

In addition, as encroachment requests are received and processed by NCTA, they will be input into the GIS.

Create and update as needed a GIS database for US 74 Express Lanes.

8. MEASURING SYSTEM EFFECTIVENESS

8.1. Express Lane Facility Performance Monitoring

In more and more urban areas across the nation, states have moved to implement Express Lanes to meet the mobility needs of a growing population and economy. From both a policy and operational standpoint, Express Lanes are more complex than other solutions such as High Occupancy Vehicle lanes (HOV) and create a need to understand how these facilities may operate over time.

Projects of this type typically present a range of policy decisions that must be addressed, some of which can be controversial. Moreover, the operating characteristics of a project are likely to change over time, requiring additional policy decisions to adjust operating strategies to match the new operating characteristics.

The process for assessing possible Express Lane operating strategies should be similar to the one used to plan a project, and should emerge from an established monitoring program. Information on vehicle and passenger volumes, travel speeds, travel-time savings, violation rates, and crashes should form the basis of an on-going monitoring and evaluation program.

Examples of goals to be considered and prioritized in shaping the design and policies for an Express Lanes project include, among others:

- Maximizing person throughput
- Managing congestion by improving system efficiency
- Providing an option for travel time savings and trip reliability
- Encouraging carpooling in peak periods
- Improving air quality
- Supporting transit service and reliability

Once agreed upon, the achievement of these goals can best be addressed by defining what metrics can most effectively and efficiently measure the performance of the facility and outlining and establishing thresholds that may trigger a change in their operation. Ideally, these metrics should be identified and agreed upon in advance of the facility's opening.

Performance criteria identified for other Express Lanes facilities have included throughput (vehicular and/or person), peak period average travel speeds and hourly volumes, average speeds in general purpose lanes, travel time savings, HOV 3 and solo driver usage, number of transponder and non-transponder based transactions and levels of service in the Express Lanes versus the general-purpose lanes.

As noted above, performance measurement should be viewed as a continuous process focused on assessing the progress made towards achieving the operational goals identified for the corridor. In essence, if you don't measure results, you can't tell success from failure; and if you can't see failure, you can't correct it.

As the Express Lane system matures, and operational experience is gained, these performance measures would likely change as new data collection methods and processing techniques are implemented.

"Success" targets should be defined for the performance measures as the project progresses. The targets should be realistic (i.e. achievable), measurable, and have sufficient data available. These "performance measures success thresholds" would provide an indication that the corridor goals have been achieved. Upon deployment of the US 74 Express Lanes, system operations below the thresholds would indicate that the project is having the desired effect. As data is collected, and models developed, the targets would be validated and goals adjusted to ensure realistic and achievable targets are used.

The “travel time reliability” performance measure specific to the US-74 Express Lanes is defined as maintaining a minimum travel speed of 45 mph for 90 percent of the time over a consecutive 180-day period during the weekday peak periods.

Performance will be monitored for each segment, as well as the entire US-74 Express Lanes project, via reports generated by both the TMC, using the data provided by vehicle detectors, within the project limits and the RTCS Toll Host. This data will also be used to generate reports to meet FHWA operational certification requirements under Section 166 of Title 23 for converted HOV lanes.

Summarizing, performance measurement is important for several reasons:

- It provides the basis for determining if the Express Lanes program is achieving its goals.
- It permits the evaluation of the effectiveness of the implemented corridor management strategies in meeting the operational goals and objectives for the corridor.
- It allows a comparison of operations from year to year as well as a comparison of performance relative to other areas or corridors.
- It provides information to decision makers, stakeholders, and to the public (e.g., justification for the continued operation or expansion of the Express Lanes project).

Develop a customize performance measures report to meet FHWA and NCTA requirements.

8.2. Financial Management & Reporting Procedures

The US-74 Express Lane Project will have a reporting system that accounts for all transactions and provides financial reconciliation of all financial transactions and revenues. Appropriate revenue, reconciliation variances, performance and operational data will be provided in reports that are complete and accurate to allow for the monitoring of operational and financial performance. Any additional report formats necessary for this project will be developed and approved during the design phase.

The Back Operating System (BOS) currently supports a complete reconciliation process to ensure all transactions and associated revenues are properly accounted for. Such functions include:

- Financial and transaction reconciliation and audit
- Financial, transaction and operational reporting
- Reciprocity with all other organizations with which NCTA has entered into an agreement (currently Peach Pass, E-Z Pass and SunPass)

The BOS in place for the Triangle Expressway includes an entire suite of financial reports, which, in addition to the functions listed above, are used to coordinate financial project reporting with NCDOT’s fiscal offices. A complete list of the 19 financial and 13 interoperability reports currently available, along with a description of their functionality, is set forth in the Triangle Expressway’s “General System Detail Design, v1.8”, dated March 31, 2015.

It is recommended and fully expected that this system will be modified to provide this full range of reports for the US 74 Express Lanes and ultimately for the I-77 Express Lanes as well.

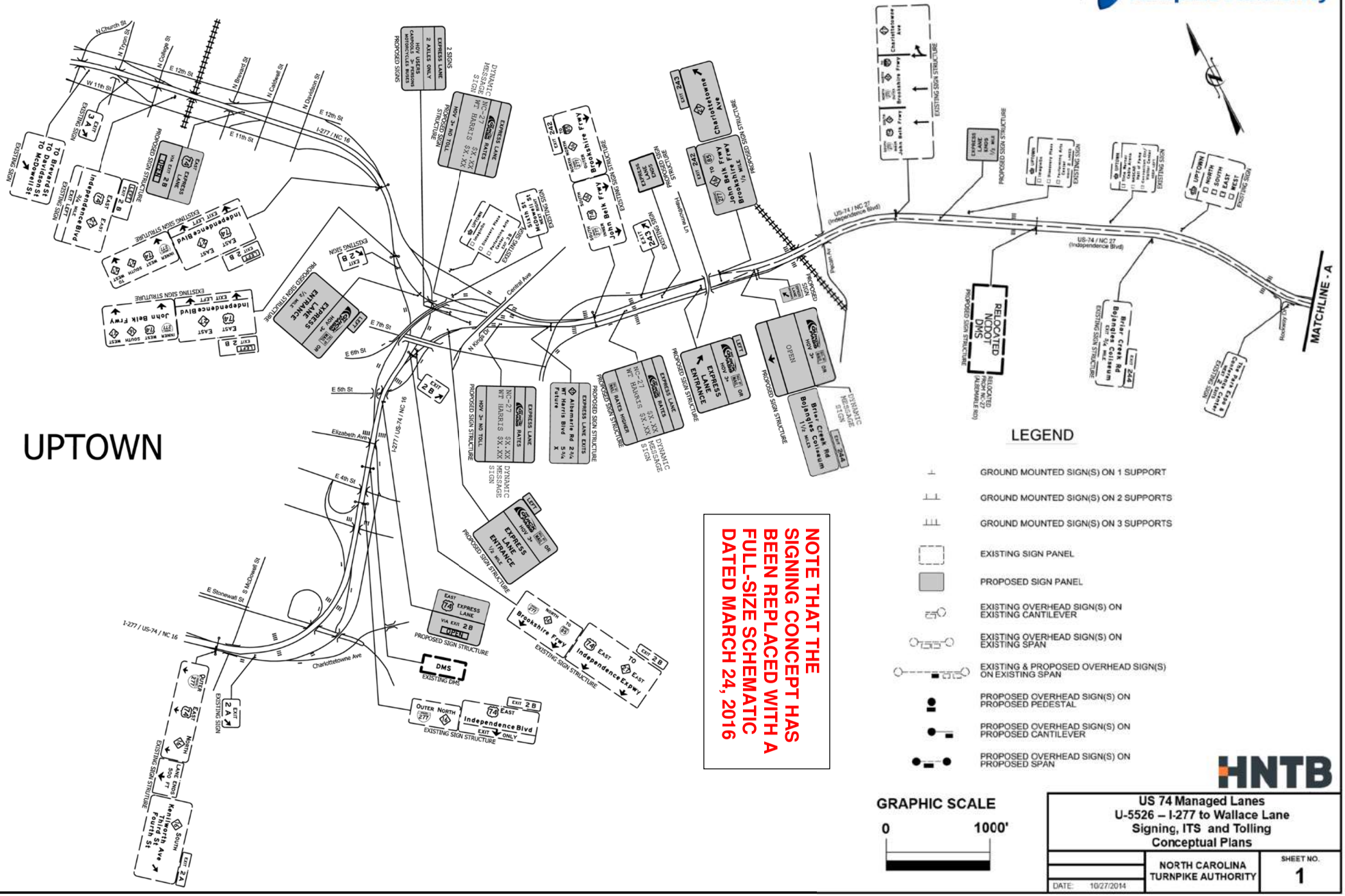
The TMS component of the RTCS will provide inputs to the back office for the determination of dynamic pricing, system monitoring, traffic detection, measure traffic volumes and Levels of Service in the Express and GP lanes and reversible lane operations

Customize Triangle Expressway financial reporting procedures for US 74 Express Lanes.

Appendices

Appendix A. US 74 Concept Plans

SIGNING CONCEPT PLAN



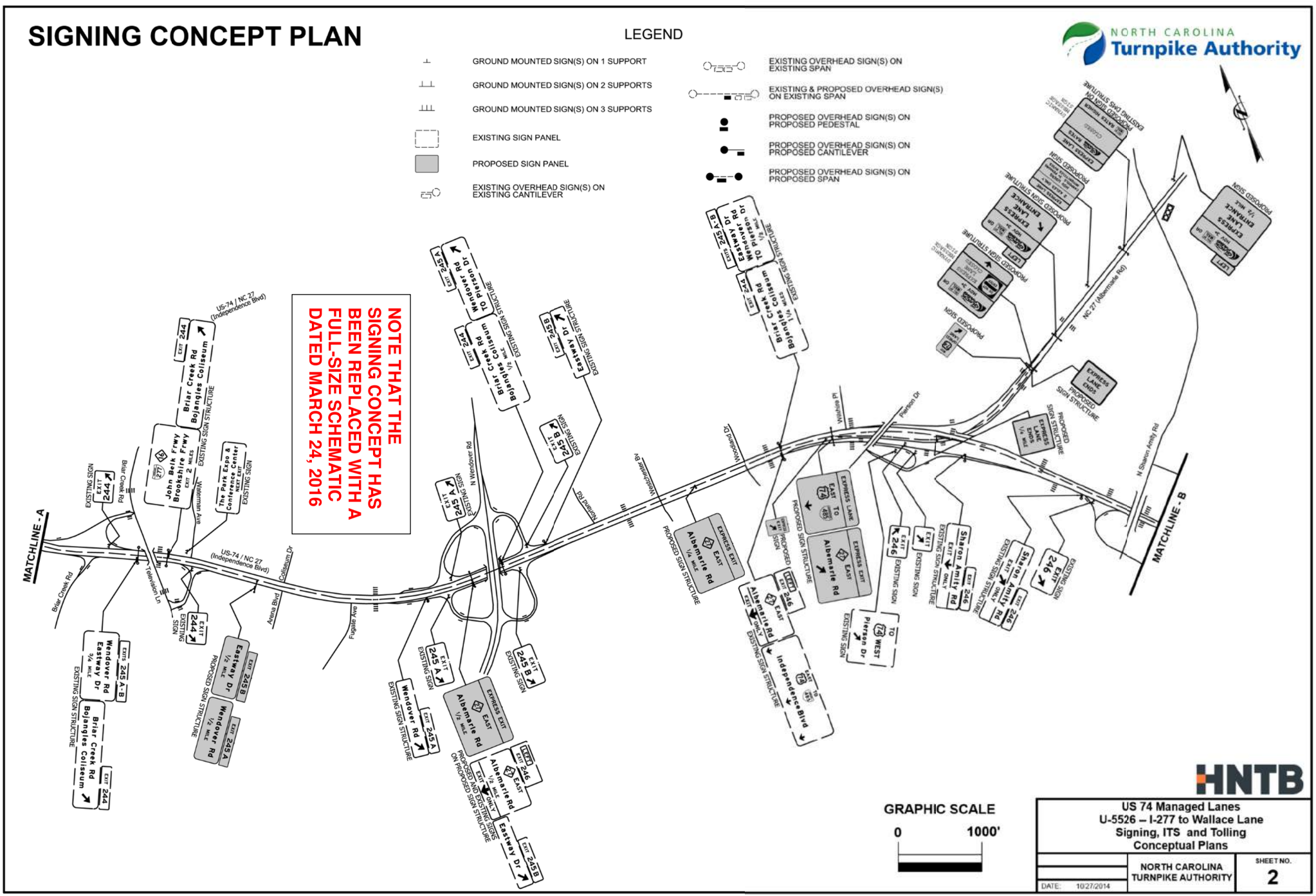
NOTE THAT THE SIGNING CONCEPT HAS BEEN REPLACED WITH A FULL-SIZE SCHEMATIC DATED MARCH 24, 2016

NORTH CAROLINA Turnpike Authority

HNTB

US 74 Managed Lanes U-5526 – I-277 to Wallace Lane Signing, ITS and Tolling Conceptual Plans	
DATE: 10/27/2014	NORTH CAROLINA TURNPIKE AUTHORITY
	SHEET NO. 1

SIGNING CONCEPT PLAN



HNTB

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
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Conceptual Plans

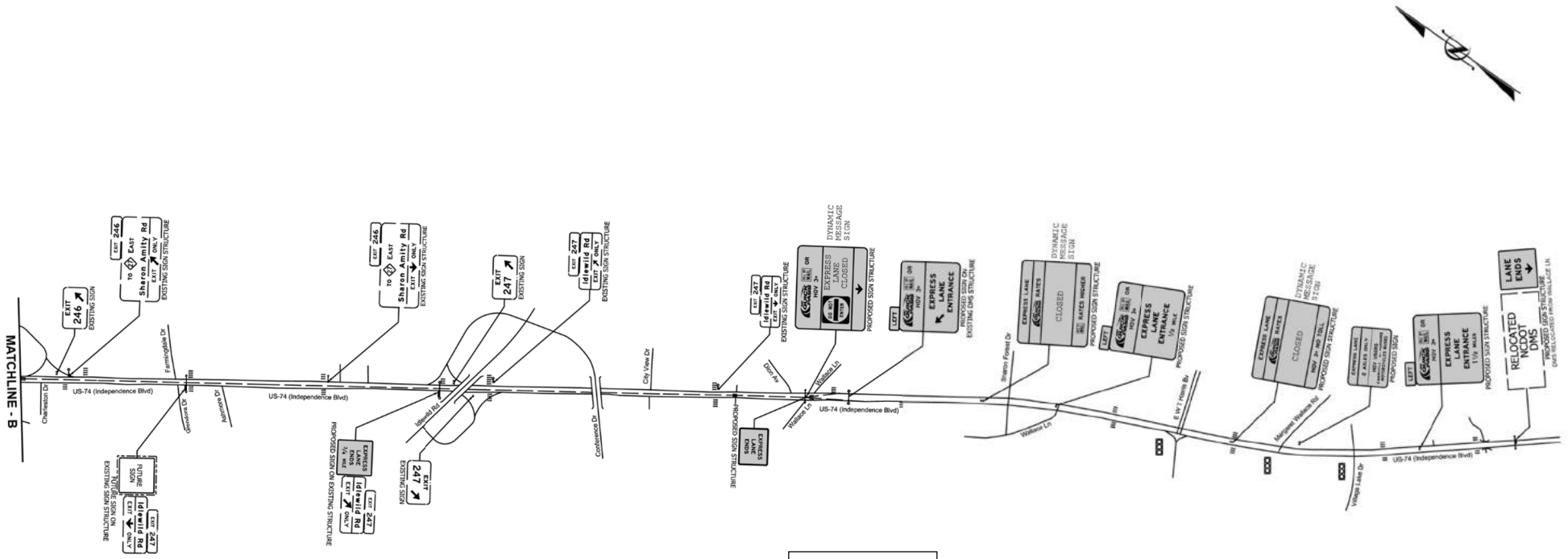
NORTH CAROLINA TURNPIKE AUTHORITY

DATE: 10/27/2014

SHEET NO. 2

SIGNING CONCEPT PLAN

NORTH CAROLINA Turnpike Authority



LEGEND

- GROUND MOUNTED SIGN(S) ON 1 SUPPORT
- GROUND MOUNTED SIGN(S) ON 2 SUPPORTS
- GROUND MOUNTED SIGN(S) ON 3 SUPPORTS
- EXISTING SIGN PANEL
- PROPOSED SIGN PANEL
- EXISTING OVERHEAD SIGN(S) ON EXISTING CANTILEVER
- EXISTING OVERHEAD SIGN(S) ON EXISTING SPAN
- EXISTING & PROPOSED OVERHEAD SIGN(S) ON EXISTING SPAN
- PROPOSED OVERHEAD SIGN(S) ON PROPOSED PEDESTAL
- PROPOSED OVERHEAD SIGN(S) ON PROPOSED CANTILEVER
- PROPOSED OVERHEAD SIGN(S) ON PROPOSED SPAN

NOTE THAT THE SIGNING CONCEPT HAS BEEN REPLACED WITH A FULL-SIZE SCHEMATIC DATED MARCH 24, 2016

GRAPHIC SCALE

0 1000'

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US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
Conceptual Plans

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SHEET NO. 3

ITS CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

TYPICAL ITS CABINET

TYPICAL DMS INSTALLATION ON TRUSS STRUCTURE

LEGEND

- DMS — PROPOSED DMS FOR TOLL RATES
- PROPOSED MANAGED LANES CAMERA
- PROPOSED DETECTOR
- PROPOSED COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED COMMUNICATIONS CABLE IN EXISTING CONDUIT
- DMS — EXISTING DMS FOR DOT/TRAFFIC MANAGEMENT
- EXISTING DOT CAMERA
- EXISTING COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED DOT CAMERA

NOTES:

1. PROPOSED MANAGED LANES CCTV CAMERAS TO BE CO-LOCATED ON SAME POLE AS EXISTING DOT CAMERAS WHERE POSSIBLE.
2. ALL EXISTING VEHICLE DETECTORS TO BE REPLACED WITH NEW DETECTORS ON EXISTING POLE WHERE POSSIBLE.
3. CONDUIT CONNECTING DEVICES EAST OF ALBEMARLE ROAD CONSTRUCTED AS A PART OF PROJECT U-209B.

GRAPHIC SCALE

0 1000'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
Conceptual Plans

NORTH CAROLINA TURNPIKE AUTHORITY

DATE: 10/27/2014

SHEET NO. 4

ITS CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

TYPICAL CCTV CAMERA SITE

2-CAMERA SITE

LEGEND

- PROPOSED DMS FOR TOLL RATES
- PROPOSED MANAGED LANES CAMERA
- PROPOSED DETECTOR
- PROPOSED COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED COMMUNICATIONS CABLE IN EXISTING CONDUIT
- EXISTING DMS FOR DOT/TRAFFIC MANAGEMENT
- EXISTING DOT CAMERA
- EXISTING COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED DOT CAMERA

NOTES:

1. PROPOSED MANAGED LANES CCTV CAMERAS TO BE CO-LOCATED ON SAME POLE AS EXISTING DOT CAMERAS WHERE POSSIBLE.
2. ALL EXISTING VEHICLE DETECTORS TO BE REPLACED WITH NEW DETECTORS ON EXISTING POLE WHERE POSSIBLE.
3. CONDUIT CONNECTING DEVICES EAST OF ALBEMARLE ROAD CONSTRUCTED AS A PART OF PROJECT U-209B.

GRAPHIC SCALE

0 1000'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
Conceptual Plans

NORTH CAROLINA TURNPIKE AUTHORITY

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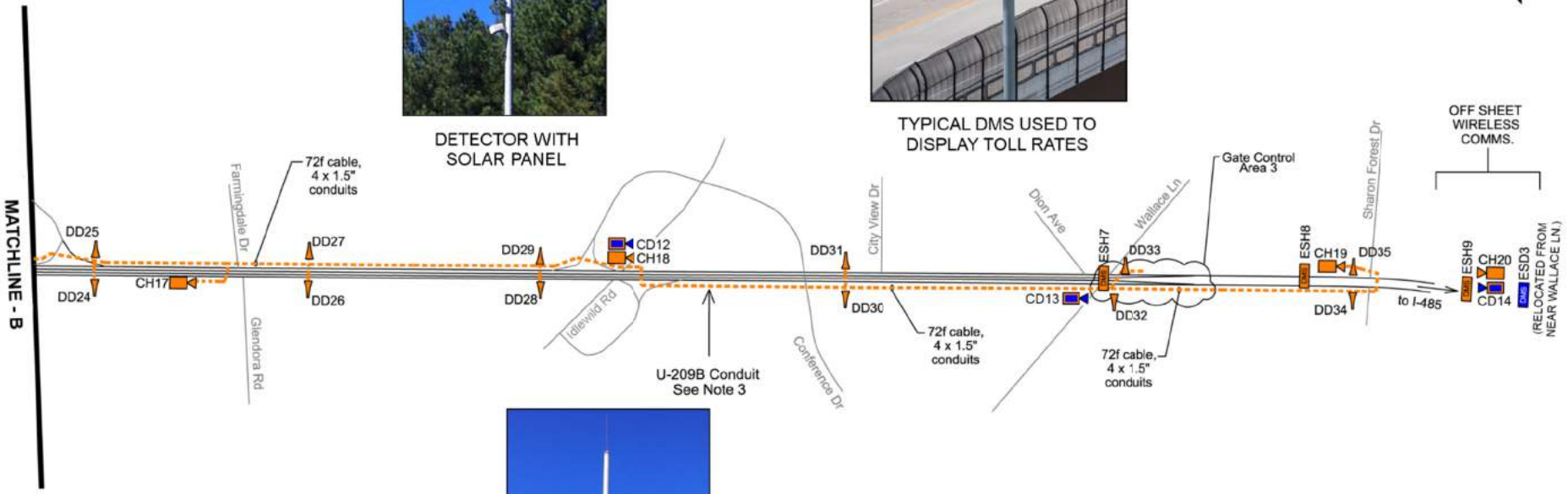
SHEET NO. 5

ITS CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

DETECTOR WITH SOLAR PANEL

TYPICAL DMS USED TO DISPLAY TOLL RATES



TYPICAL DETECTOR SITE

NOTES:

1. PROPOSED MANAGED LANES CCTV CAMERAS TO BE CO-LOCATED ON SAME POLE AS EXISTING DOT CAMERAS WHERE POSSIBLE.
2. ALL EXISTING VEHICLE DETECTORS TO BE REPLACED WITH NEW DETECTORS ON EXISTING POLE WHERE POSSIBLE.
3. CONDUIT CONNECTING DEVICES EAST OF ALBEMARLE ROAD CONSTRUCTED AS A PART OF PROJECT U-209B.

LEGEND

- DMS — PROPOSED DMS FOR TOLL RATES
- PROPOSED MANAGED LANES CAMERA
- PROPOSED DETECTOR
- PROPOSED COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED COMMUNICATIONS CABLE IN EXISTING CONDUIT
- DMS — EXISTING DMS FOR DOT/TRAFFIC MANAGEMENT
- EXISTING DOT CAMERA
- EXISTING COMMUNICATIONS CABLE AND CONDUIT
- PROPOSED DOT CAMERA

GRAPHIC SCALE

0 1000'

ATKINS

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U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
Conceptual Plans

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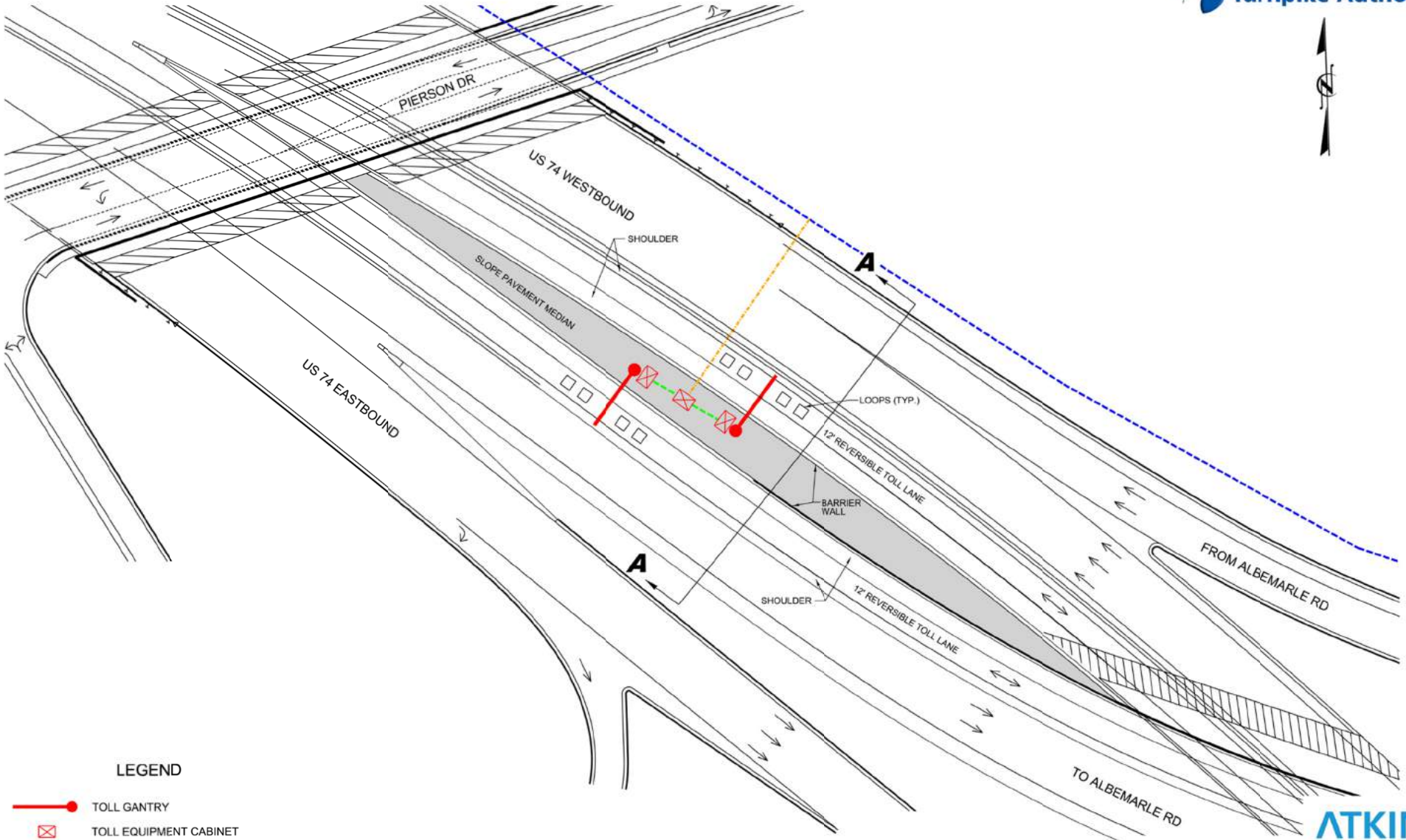
SHEET NO. 6

TOLL SITE CONCEPT PLAN

NORTH CAROLINA Turnpike Authority



LEGEND

- TOLL GANTRY
- TOLL EQUIPMENT CABINET
- EXISTING FIBER-OPTIC COMMUNICATIONS CABLES AND CONDUIT
- PROPOSED FIBER-OPTIC COMMUNICATIONS CABLES AND CONDUIT
- PROPOSED TOLL COMMUNICATIONS CABLE

GRAPHIC SCALE

0 100'

ATKINS

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U-5526 – I-277 to Wallace Lane
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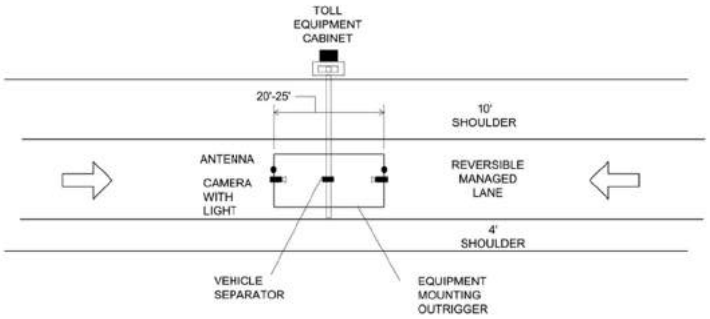
SHEET NO. 7

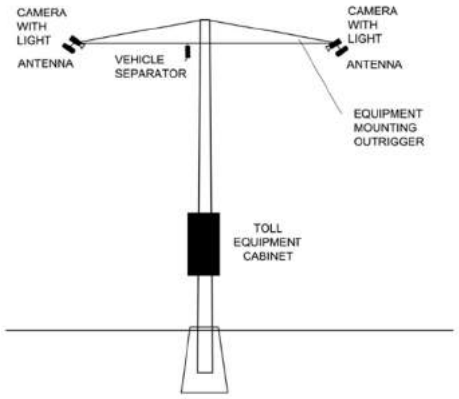
TOLL SITE DETAILS

NORTH CAROLINA Turnpike Authority



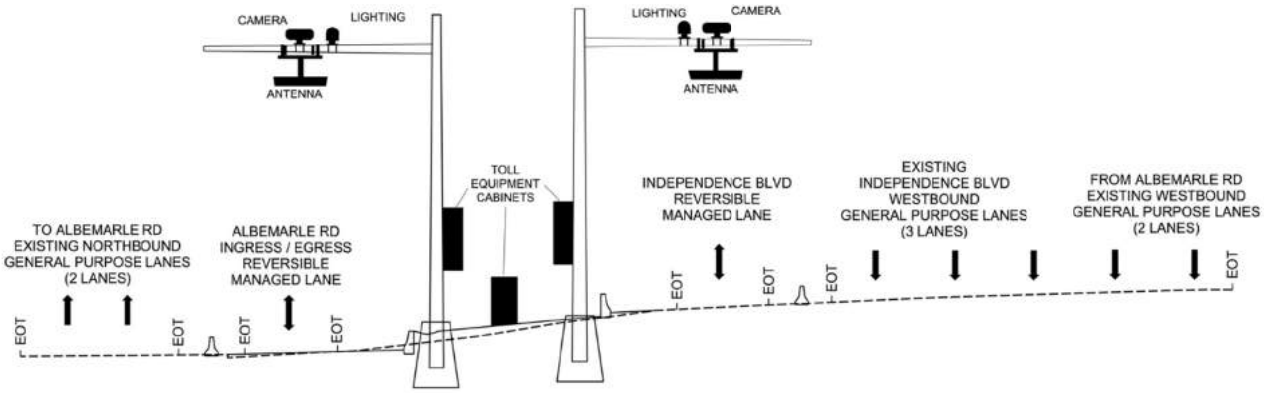
TOP VIEW

SAMPLE OUTRIGGER



SIDE VIEW

TYPICAL MANAGED LANES TOLL GANTRIES



X-SECTION VIEW A-A

ATKINS

NOT TO SCALE

US 74 Managed Lanes U-5526 – I-277 to Wallace Lane Signing, ITS and Tolling Conceptual Plans		
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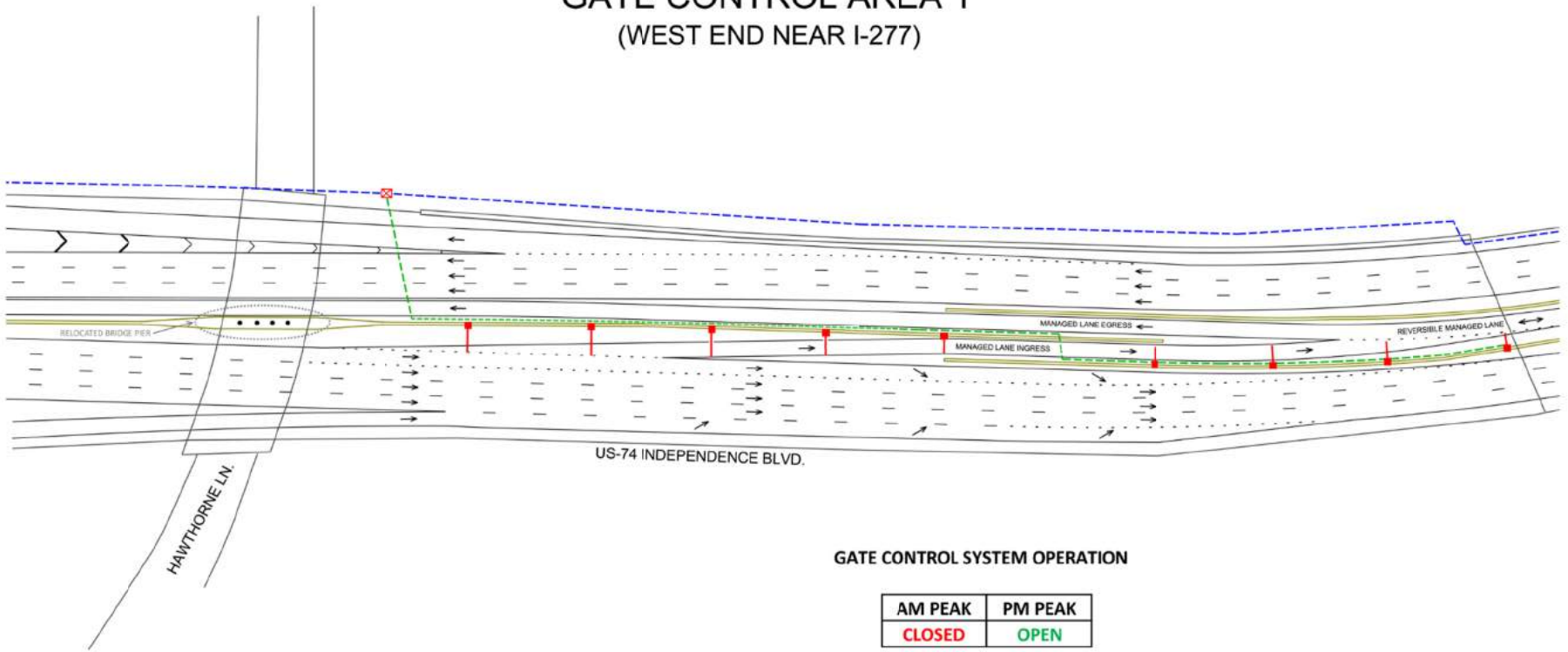
GATE SYSTEM CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

GATE CONTROL AREA 1
(WEST END NEAR I-277)



GATE CONTROL SYSTEM OPERATION

AM PEAK	PM PEAK
CLOSED	OPEN

LEGEND

- GATE
- GATE CONTROLLER CABINET
- GATE SYSTEM COMMUNICATION CABLE
- EXISTING COMMUNICATION CABLE AND CONDUIT
- CONCRETE BARRIER

GRAPHIC SCALE

0 100'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
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NORTH CAROLINA TURNPIKE AUTHORITY

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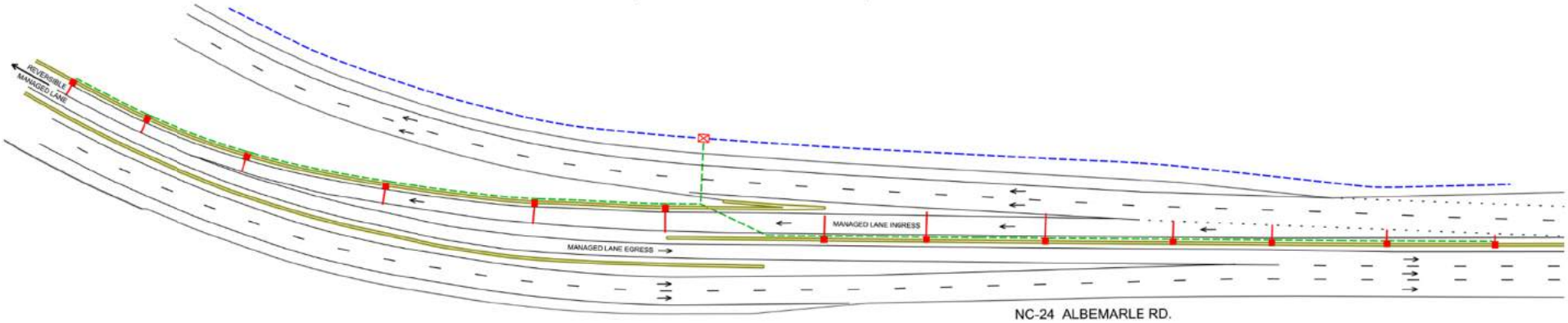
GATE SYSTEM CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

GATE CONTROL AREA 2
(ALBEMARLE ROAD)



GATE CONTROL SYSTEM OPERATION

AM PEAK	PM PEAK
OPEN	CLOSED

LEGEND

- GATE
- GATE CONTROLLER CABINET
- GATE SYSTEM COMMUNICATION CABLE
- EXISTING COMMUNICATION CABLE AND CONDUIT
- CONCRETE BARRIER

GRAPHIC SCALE

0 100'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
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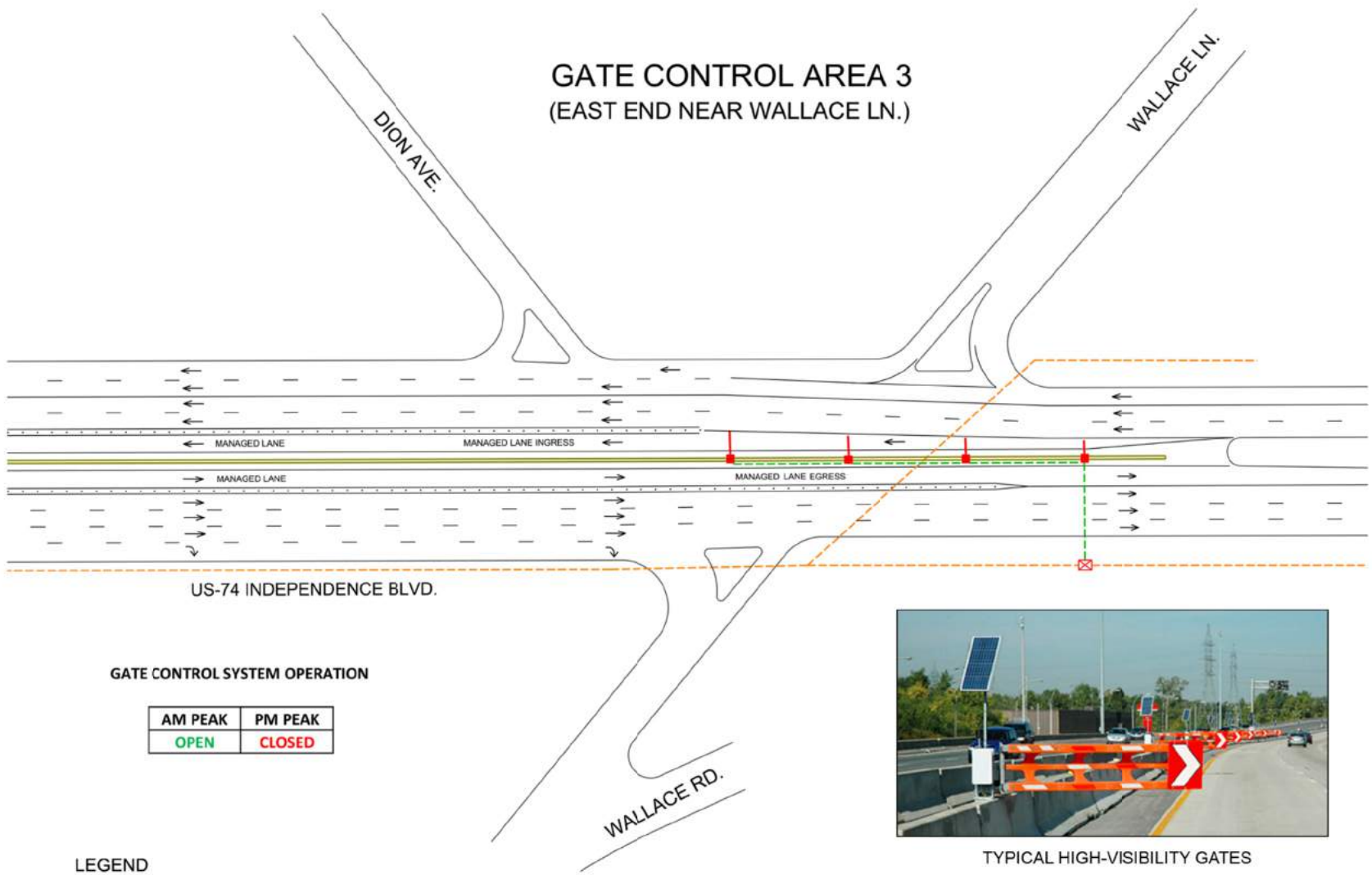
SHEET NO. 10

GATE SYSTEM CONCEPT PLAN

NORTH CAROLINA Turnpike Authority



GATE CONTROL SYSTEM OPERATION

AM PEAK	PM PEAK
OPEN	CLOSED

TYPICAL HIGH-VISIBILITY GATES

LEGEND

- GATE
- GATE CONTROLLER CABINET
- GATE SYSTEM COMMUNICATION CABLE
- PROPOSED COMMUNICATION CABLE IN EXISTING CONDUIT
- CONCRETE BARRIER

GRAPHIC SCALE

0 100'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
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NORTH CAROLINA TURNPIKE AUTHORITY

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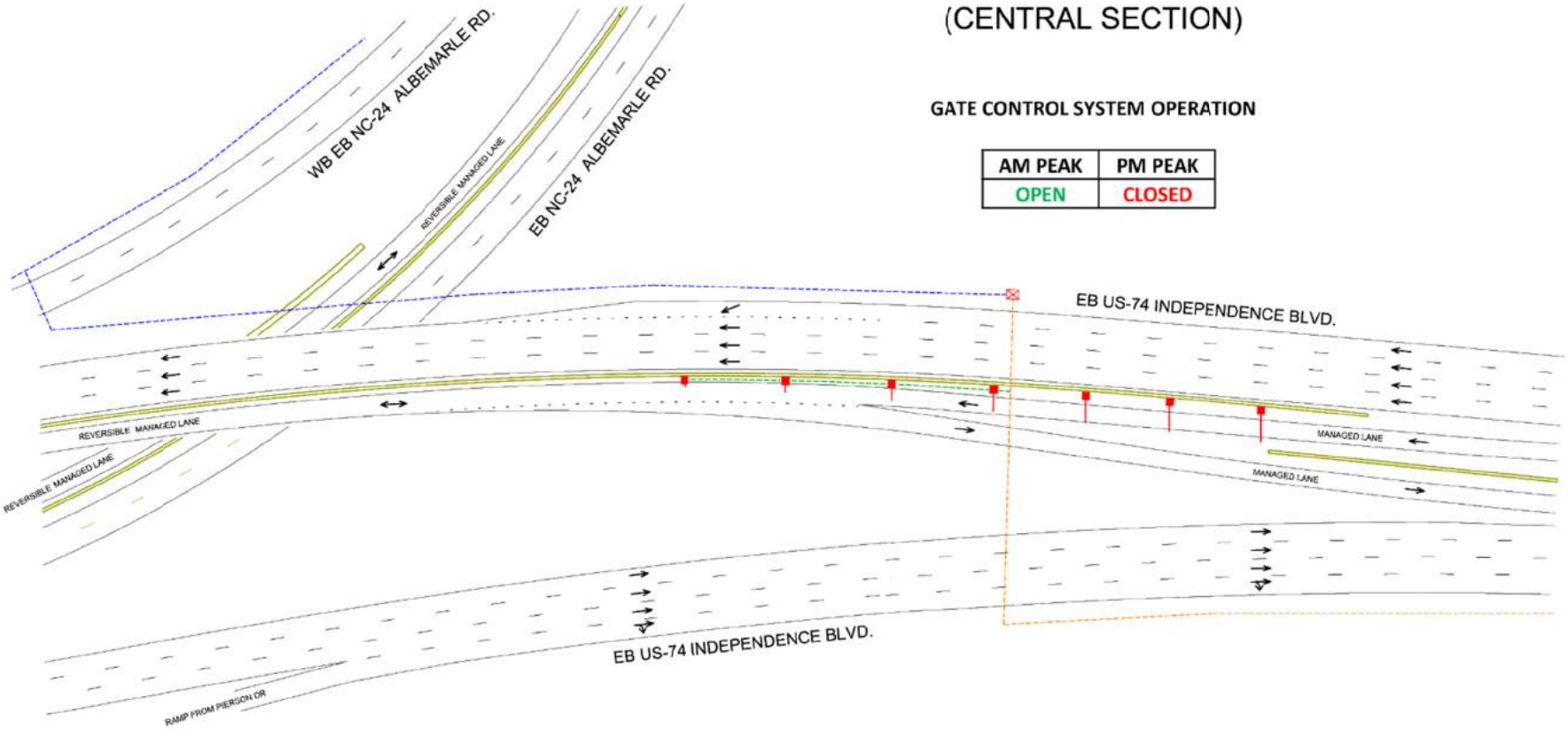
GATE SYSTEM CONCEPT PLAN

NORTH CAROLINA Turnpike Authority

GATE CONTROL AREA 4
(CENTRAL SECTION)

GATE CONTROL SYSTEM OPERATION

AM PEAK	PM PEAK
OPEN	CLOSED



LEGEND

- GATE
- GATE CONTROLLER CABINET
- GATE SYSTEM COMMUNICATION CABLE
- PROPOSED COMMUNICATION CABLE IN EXISTING CONDUIT
- EXISTING COMMUNICATION CABLE AND CONDUIT
- CONCRETE BARRIER

GRAPHIC SCALE

0 100'

ATKINS

US 74 Managed Lanes
U-5526 – I-277 to Wallace Lane
Signing, ITS and Tolling
Conceptual Plans

NORTH CAROLINA TURNPIKE AUTHORITY

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SHEET NO. 12

Appendix B. Sample Trip Calculation

Example Trip Calculation:

During the morning rush into town, US 74 reversible, speeds northbound are measured at the between 7:15 am and 7:20 am:

- General purpose lanes, location #1 – 11 mph
- General purpose lanes, location #2 – 8 mph
- Express Lane, location #1 – 47 mph
- Express Lane, location #2 – 49 mph

The average speeds at each measured location are averaged together in order to calculate the average segment speed. This is also performed for both the Express Lanes and the General Purpose Lanes.

Location5	Speed Sample	Average Speed Segment	Average Segment Travel Time (6 miles)	Travel Time Savings
GPL Location 1	11	9.5 mph	38 minutes	30.5 minutes
GPL Location 2	8			
EL Location 1	47	48 mph	7.5 minutes	
EL Location 2	49			

- Based on the figures provided above the average segment speeds were calculated.
- The average segment travel time is to be calculated for both the Express Lane and the general purpose lanes.
- A travel time savings is calculated subtracting the Express Lane travel time from the general purpose lanes travel time. In the event that the difference is negative (i.e. The ML travel time is longer), the value would be set equal to 0.
- The patron of the Express Lane would save 30.5 minutes on average.
- The speed in the Express Lane is also checked against the minimum acceptable speed in the Express Lane.
- For each segment, the following adjustments are made to the current value of travel time.

Based on the results, each subsequent calculation period, there would be a re-evaluation of the savings and adjustments made to the pricing.

- If at any downstream segments average speed in the Express Lane has been unacceptable (i.e. lower than the minimum acceptable speed of xx mph) for 2 consecutive evaluation periods of time, then the Value of Travel Time at that segment is increased by an incremental Value associated with the Value of Travel Time.
- For example, consider a southbound patron entering at the segment at US 74. If the average speed in the Express Lane dipped below xx mph for two consecutive evaluation periods, segments to the south (Future) would then be adjusted by the Incremental Value of Travel Time.(XX ¢ per minute)
- If at all downstream segments average speeds in the Express Lane have been acceptable for two consecutive evaluation periods, then the Value of Travel Time at that segment would be decreased by the incremental Value of Travel Time. (This would typically occur after the peak period, when volumes taper off and speeds improve.
    - In all other situations, the Value of Travel Time would be unchanged.
    - The Value of Travel Time would not drop below the standard Value of Travel Time.

[5] The number of samples may vary based on the segment length. Two are used for simplicity.

The value of travel time savings is calculated by taking the current value of travel time and multiplying it by the total downstream time savings.

In the above example, if the value of travel time were 24¢/minute, and the total travel time savings were 30.5 minutes, then the value of travel time savings would be equal 24¢/minute * 30.5 minutes, or $7.32. This equates to $1.22 per mile.

- The nominal entry rate per mile is then compared to the minimum and maximum rates.
- If the nominal rate is lower than the minimum rate, then the minimum rate per mile takes precedence.
- If the nominal rate lies between the minimum and maximum rates, then the nominal rate takes precedence.
- If the nominal rate is higher than the maximum rate, then the entry point should be closed to Single Occupancy Vehicles.

This is one of the typical methods utilized to manage the traffic in the Express Lanes and has various permutations based on the actual site geometry. If there are more segments, the algorithm can be adapted to accommodate the various speeds by adding a multiplier for the segments.

Appendix C. Toll Adjustment Procedures

Traffic data will be collected over a defined interval (e.g. 3, 5 or 15 minutes). This interval will be able to be modified by non-technical personnel. The Traffic Density (vehicles/mile/lane) will be computed from vehicle counts and speeds as follows:

Traffic Density = ((C/P)*3600)/(S*N)

Where: C = the total vehicle count over the period.
P = Length of the measurement period in seconds.
S = Average measured vehicle speed over the period in mph.
N = the number of lanes in operation at a specific tolling zone in a particular traffic direction.

Traffic density is correlated to Level of Service using the table that is presented below as Table 3, which is based on data obtained from FHWA.

Keyword	Definition
Level of Service (LOS)[6]	1) A qualitative assessment of a road's operating conditions. For local government comprehensive planning purposes, level of service means an indicator of the extent or degree of service provided by, or proposed to be provided by, a facility based on and related to the operational characteristics of the facility. Level of service indicates the capacity per unit of demand for each public facility. 2) This term refers to a standard measurement used by transportation officials which reflects the relative ease of traffic flow on a scale of A to F, with free-flow being rated Level of Service-A and congested conditions rated as Level of Service-F.

Traffic Table 3[7]		
Level Of Service (LOS)	Description	Traffic Density (Vehicles/Lane/Mile)
A	Free flow with low volumes and high speeds.	0–11
B	Reasonably free flow, but speeds beginning to be restricted by traffic conditions.	>11–18
C	In stable flow zone, but most drivers are restricted in the freedom to select their own speeds.	>18–26
D	Approaching unstable flow; drivers have little freedom to select their own speeds.	>26–35
E	Unstable flow; may be short stoppages	>35–45
F	Unacceptable congestion; stop-and-go; forced flow.	>45

Example: A 6-minute count of 120 vehicles traveling in an HOV/Express lane at 55 mph would result in a traffic density of 21.8 or Level of Service “C”.

[6] http://www.fhwa.dot.gov/planning/glossary/glossary_listing.cfm?sort=definition&TitleStart=L
[7] http://www.fhwa.dot.gov/environment/publications/flexibility/ch04.cfm

((120/360)*3600)/55*1).

This would translate into 1,200 vehicles per hour with a 55 mph free-flow speed.

Traffic densities at a single Vehicle Detector Station (VDS) may be impacted by environmental or geometric conditions and, therefore, misrepresents the actual traffic condition within a zone of the Express Lanes. To address any misrepresentation, a coefficient must be determined and applied to any affected Traffic Density (TD).

Below is an example of how the weighted Traffic Density could be calculated. In this example, as presented in Table 4, the North Zone may have a higher coefficient than the other tolling zones, to account for its geometric conditions (e.g. length and grade, unidirectional, lane separation). The table of coefficients would contain one row for each Express Lane ingress location and one column for each tolling zone. In this case there is a direct correlation between tolling zones and ingress locations.

Tolling Zone Coefficients			
Zone "N"	**Tolling Zones**		
Ingress Location	**Point 1**	**Point 2**	**Point 3**
North	1.2	1.1	1
Central	0	1.1	1
South	0	0	1

Table 4 – Tolling Zone Coefficients

The Traffic Density is used in the toll rate setting function, so that the toll rate will adjust up or down based upon the change in the Express Lane Traffic Density. The change in the Traffic Density is the current Traffic Density minus the previously calculated Traffic Density. Express Lane Traffic Density deviations might result in small or no change to the toll rates. Large deviations will typically result in dramatic changes to the toll rates. During the process of developing the dynamic pricing algorithm business rules, NCTA staff would determine what the minimum change for rate adjustments would be in order to support the process of displaying the current toll for a particular tolling zone. A minimum toll will be assumed.

In addition to determining the Traffic Density at each Vehicle Detector Station location, the variation of Traffic Density along the Express Lanes due to the impacts of traffic entering and exiting the facility will be carefully considered. This is necessary to manage the number of vehicles entering the Express Lanes at any given point and to reduce their impact on downstream traffic congestion. This will be accomplished by assigning each Vehicle Detector Station to a specific ingress point for the calculation of the toll rate.

Toll rate increments for changes within Level of Service "A", "B", and "C" will be small, but increments for Level of Service "D" will be higher. As the Traffic Density approaches the upper end of "D", the rates would climb high enough to discourage additional toll-eligible vehicles from entering the Express Lanes. The toll rate would become prohibitively high at Level of Service "E". The algorithm will reserve a buffer as the toll approaches a dynamically established threshold for limiting ingress to HOV only so the continued ingress of HOV traffic does not cause the speed to fall below 45 mph. The threshold will be established from an average historical trend of HOV usage in the Express Lanes for the same time period and season.

The Express Lanes Traffic Density rate changes would typically be determined from the following:

- The current toll rate being charged;
- The Level of Service represented by the maximum Traffic Density at the downstream tolling locations;
- The largest traffic density (LTD) of the previous toll rate adjustment period; and
- The toll rate that is assigned to the change in LTD.

The system will compute the Traffic Density at each Vehicle Detector Station downstream from each tolling location and then select the LTD as described in the below formula.

$LTD_n = MAX\ (A_{n1}*TD_1, A_{n2}, *TD_2, \ldots A_{nj}*TD_j)$

Where $A_{n,j}$ represent a set of definable coefficients, there is one set of coefficients for each Express Lane entrance location each member of the set is used to multiply the Traffic Density in its tolling zone in a manner that reflects the characteristics of that particular zone. The arrangement presumes that there are “n” Express Lane entry points and “j” tolling zones in the direction of travel. MAX (. . .) represents a function that selects the largest member from a set of values.

The LTD values for each 20-second period would be collected from each of the Express lane sections over a fixed time period (e.g. 3 or 5 minutes) and the average of these LTDs is the final Traffic Density for the selected period. The Express Lane tolling system would then compute a toll rate adjustment for the entry point based on the computed final Traffic Density, as discussed above. The new toll rate would be determined by adding the incremental toll adjustment found in the Traffic Density rate of change table to the current toll.

Traffic increase patterns are not the inverse equivalent of traffic decrease patterns. Therefore, toll rates should not decrease at the same rate of increase. To account for this difference, a minimum and maximum toll rate adjustment for each Level of Service would need to be established. As the toll rate is incrementally adjusted, these minimum and maximum toll rates would be used to ensure that the calculated rate does not change dramatically in a short period of time. Dramatic changes may lead to erratic, sudden and unsafe behavior by users at access locations after a prospective user sees a dramatic toll change on the upstream CMS.

Appendix D. EPMO Coordination and Compliance

D.1. Project Initiation

- Feasibility
- Costs for the Initiation and Planning phases
- Budget related information
- Enterprise Architecture Questionnaire
- Security Questions
- Service Component Reference Model (to be completed by EPMO)
- Project Manager Interview (to be completed by EPMO)
- Proposed Budget – Level 1 Budget Cost Tab
- Financial Benefits – Level 1 Benefit Tab
- Alternatives Analysis
- Business Driver Impact Statements – Strategic Impact Tab
- Summary Risk Profile – Risk Tab
- Procurement Plan

D.2. Initiation Phase Requirements

Step	Description	Inputs	Outputs	Resources
1	Establish the Feasibility Study Team		Team Roster	Project Manager and Project Sponsor
2	Prepare and obtain signatures approving the initial project scope	Application Notification	Approved Scope Statement	Project Manager and Project Sponsor and other client management where appropriate
3	Develop an initial description of the relevant, existing business process	Application Notification, Any Existing Workflow or Business Process Documents	Initial Process Description and/or workflow diagram	Team/process experts
4	Identify Problems and Opportunities Associated with the Business Process	Process description and Associated Workflow Diagrams	Statement of Problems, Opportunities	Team/process experts
5	Brainstorm Alternative Solutions and Related Advantages and Disadvantages	Process Description and/or Any Associated Workflow Diagrams, Statement of Problems, Opportunities	List of Alternatives with Respective Advantages and Disadvantages	Team/process experts/tech-nology experts

6	Select Preferred Alternative and Conduct Cost/Benefit/Risk Analysis	List of Alternatives with Respective Advantages and Disadvantages, Process Description and Associated Workflow Diagrams, Statement of Problems, Opportunities	Cost/Benefit/Risk Analysis and Recommendation	Team
7	Prepare Feasibility Study Report	Results from Previous Steps	Feasibility Study Report	Team
8	Obtain Approval and Commitment to Continue	Feasibility Study Report	Signed Feasibility Study Report	Team, Project Sponsor

Procurement of a new vendor and system that is not part of or included as a feature of the existing system will require all tasks to be completed as part of the approval process.

If existing BOS and RTCS Contractor is used, some of the existing documents will be waived from resubmission.

D.3. Planning and Design Requirements

Step	Description	Inputs	Outputs	Resources
1	Establish Business Requirements Design Team			Project Manager/ Project Sponsor
2	Review Documentation	List of Alternatives with Respective Advantages and Disadvantages, Process Description and Associated Workflow Diagrams, Statement of Problems, Opportunities		
3	Validate and Refine Initial Process Description	Process Description and Any Associated Workflow Diagrams, Statement of Problems, Opportunities	Process Description and Any Associated Workflow Diagrams, Statement of Problems, Opportunities	Team

4	Define Application Business Requirements	Process Description and Any Associated Workflow Diagrams, Statement of Problems, Opportunities	Application Business Requirements	Team
5	Where appropriate redesign the original process to enhance productivity, enable cost savings, and/or improve customer service.	Final Process Description and Any Workflow Diagram, Refined Statement of Problems, Opportunities, Application Business Requirements	Recommended Process Changes, Process redesign matrices	Team
6	Determine High-level Application Functionality	Recommended Process Changes, Process redesign matrices, Final Process Description and Workflow Diagram, Business Requirements	High-level Application Functionality Document	Team
7	Develop High Level Data Model	High-level Application Functionality Document, Recommended Process Changes, Process redesign matrices, Final Process Description and Workflow Diagram, Business Requirements	High Level Data Model	Team/ DBA
8	Review and revise initial cost and risk estimates	Original cost/benefit/ risk analysis Final Process Description and Workflow Diagram, Business Requirements	Revised cost and risk estimates	Project Manager/ Team
9	Prepare Business Requirements and Conceptual Design Report	Results from Previous Steps	Draft Business Requirements and Conceptual Design Report	Team
10	Select Quality Assurance Team		Quality Assurance Team Roster	Team
11	Quality Assurance Review	All Business Requirements, Functionality, and Data Modeling Documents.	Quality Assurance Comments, Formal QA plan identifying QA goals and defect prevention activities	Quality Assurance Team
12	Incorporate Quality Assurance Comments and Plan	Quality Assurance Comments, Formal QA plan identifying QA goals and defect prevention activities	Final Business Requirements and Conceptual Design Report	Team

13	Obtain Approval and Commitment to Continue	Business Requirements and Conceptual Design Report	Signed Business Requirements and Conceptual Design Report	Team, Project Sponsor

D.4. Execution and Build Requirements

The 'Detailed Design' section of the Technical Architecture System Design document will be the focal point of this phase. Security considerations, Network and Bandwidth issues and hardware topology will be finalized and the entire Technical Architecture System Design document should be forwarded to Enterprise Technology Strategies (ETS) – the technical branch of the EPMO. It should be noted that the Technical Architecture document consists of architecture-related information that the SCIO requires as the Exit Criteria for the Execution and Build Phase. It is therefore advisable to create a Project-related System Design Document (SDD) as a parallel exercise. The following aspects of software design should be covered in it:

- Identify & Document System Components & Interfaces
- Identify & Document Design Constraints
- Identify & Document Future Contingencies
- Identify & Document System Internal Communications
- Identify & Document User/Operator Input Media and Devices
- Document the details of Hardware Design to address Memory and Storage, Processor speed and functionality (Fail-Over & Load Balancing concerns)
- Hardware Client requirements (Hard Drive capacity, Monitor, etc.)
- Operating System requirements, including Version)

The following documents will also have to be created in the Execution and Build Phase:

- Disaster Recovery/Business Continuity Plan
- Test and Acceptance Results (compared to the Acceptance Criteria in the previous phase
- Results of a Pilot, if the Department opts to develop a pilot prior to the main development effort
- Operations and Maintenance Transition Plan (It should be noted that the total cost of project investment is the total cost of all phases plus 5 years of Operational costs).

D.5. Implementation Requirements

The following documents will be required to be produced for the Implementation Phase:

- Project Status Reporting (to the EPMO QA Group)
  Project status reporting to the ITS EPMO Quality Assurance staff is to be accomplished via the PPM Tool. The flow of project status reporting is controlled with the use of the "Project Status Report Step" attribute (referred to as "status" for short in this section). This field is found on the "Status Tab" near the bottom (just above the "Accomplishments this Period" section).

The following Activities also have to be planned and executed for the Implementation Phase:

- TRAINING: Execute the Reviewed and Approved Training Plan that had been created as a deliverable in the Planning & Design Phase. Refer to the MS Project Plan, under Implementation Phase for detailed tasks to be completed.
- DEPLOYMENT & ROLLOUT: Execute the Reviewed and Approved Rollout Plan that had been created in the Planning & Design Phase. Refer to the MS Project Plan, under Implementation Phase for detailed tasks including tasks to be completed for setting up the User environment.

D.6. Closeout Requirements

Gate Approval for the Closeout Phase is not required by the SCIO. In fact, the only major activity that the EPMO QA team needs to complete is a Project Closeout Review. The completed documents should be included under the Document Management tab and the EPMO QA team should be informed, so that they may initiate the review.

The final testing should be complete by the time that the project is ready for closeout.

D.7. Additional Details of EPMO Coordination and Compliance

Two of the areas under the oversight by the EPMO office that apply to the Tolling Systems in North Carolina include:

Project Portfolio Management (PPM) – supports the governance and management of IT implementation projects at the project, agency, and state levels. The software tool provides the following capabilities:

- A workflow process that encompasses project approvals, checkpoint reviews and periodic (monthly) status reporting
- A gated review and approval approach at governance hierarchy levels – due diligence path to ensure past work is acceptable and the project is positioned to complete the succeeding phase successfully
- Administrative support for sequencing of development and project management that follow industry recognized best practices for system development life cycle (IEEE) and project management (PMI); and

Applications Portfolio Management (APM) – supports the management of applications assets to minimize risks and optimize benefits-costs over their useful life cycle.

Key activities are:

- Inventory applications by collecting relevant data in the areas of basic identification and use, technical and business status and risk profile
- Assessment, using a variety of criteria. The criteria include agreement with agency business strategies or governmental priorities, benefits and value to agency missions or business processes, costs to maintain and operate, ability to meet current and future agency business requirements, operational performance, technical status, and risks
- Identify areas of over and under investment in operations and maintenance and reallocate funds to give the most benefit or greatest value for monies spent
- Develop management plans (called roadmaps) for applications. The plans include strategic planning, prioritization, cost analysis, and timelines for continued operation and maintenance, enhancement, renovation, consolidation, elimination, or replacement

Legislative Responsibility

- The State CIO (SCIO) has legislative oversight authority to review and approve State agency IT projects; to develop standards and accountability measures for IT projects (including criteria for adequate project management); to require status reporting; to assign a project management advisor (PMA); and, if necessary, to suspend projects.
- Ensure that quality IT projects are delivered in a cost effective and timely manner meeting all state technical and security requirements.
- IT consolidation is optimized.

- Avoid the duplication of Information Technology capabilities and resources across State agencies.

Agencies must use the State infrastructure to host their applications unless the SCIO grants an exception based upon technology requirements and/or OSBM grants the exception based upon cost savings.

The purpose of this legislation is to help to ensure that quality IT projects are delivered in a cost effective and timely manner to the State of North Carolina.

Statutory Requirements

G.S. 147-33.72C – Project Approval

Project Review and Approval -- The State Chief Information Officer (SCIO) shall:

- Review all State agency information technology projects that cost or are expected to cost more than five hundred thousand dollars ($500,000), whether the project is undertaken in a single phase or component or in multiple phases or components.
- Approve projects that meet established quality assurance requirements.
- Establish thresholds to determine when projects costing less than $500,000 must be reviewed and approved.

Project Implementation

- No State agency shall proceed with an information technology project until the SCIO approves the project.

Suspension of Approval

- The SCIO may suspend the approval of any information technology project that does not continue to meet the applicable quality assurance standards.
- The SCIO must specify in writing to the agency the grounds for suspending the approval of any project.
- The SCIO must notify OSBM and OSC when a project has been suspended.
- OSBM shall not allow any expenditure of funds for a project that is no longer approved by the SCIO

G.S. 147-33.72D – Agency/State CIO Dispute Resolution

- When the SCIO has denied or suspended the approval of an information technology project, or has denied an agency's request for deviation, the agency may request a committee review of the SCIO‟s decision.
- The agency shall submit a written request for review to the State Controller within 15 working days following the agencies receipt of the State CIO‟s written grounds for denial or suspension.
- The review committee shall consist of the State Controller, the State Budget Officer, and the Secretary of Administration. The State Controller shall serve as the chair of the review committee.
- Within 30 days after initial receipt of the agency’s request for review, the committee shall notify the agency and the SCIO of the decision in the matter. The notification shall be in writing, and shall specify the grounds for the committee’s decision.

G.S. 147-33.72E Project Management Responsibilities

Agency

- Must provide a project manager, subject to the review and approval of the SCIO, for projects that require SCIO approval.
- Agency project managers must provide periodic reports to the PMA.

State Chief Information Officer (SCIO)

- Must designate a project management assistant (PMA) for a project that receives approval and is expected to cost more than $1 million, whether the project is undertaken in single or multiple phases or components.
- May designate a project management assistant for any other information technology project.

EPMO / Project Manager Advisor (PMA)

- Be aware of all project meetings during the project lifecycle and have the ability to attend meetings as needed.
- Advise the agency with the initial planning of a project, the content and design of any request for proposals, contract development, procurement, and other technical reviews.
- Monitor agency progress in the development and implementation of the project.
- Provide status reports to the State Chief Information Officer, including recommendations regarding continued approval of the project

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SECTION 6A.2. (d) Agency Projects. – Prior to initiation, any information technology project, or any segment of a multipart project, costing more than two hundred fifty thousand dollars ($250,000) shall be included in the agency's most recent information technology plan and shall be approved by the General Assembly.

SECTION 6A.2. (f) Information Technology Hosting. State agencies developing and implementing information technology projects/applications shall use the State infrastructure to host their projects. An exception to this requirement may be granted only if approved by both the State Chief Information Officer on the basis of technology requirements and by the Office of State Budget and Management based on cost savings.

SECTION 6A.3 The State Chief Information Officer, through the Enterprise Project Management Office, shall develop a plan and adopt measures to avoid the duplication of information technology capabilities and resources across State agencies.

Although the Triangle Expressway was imitated outside these constraints, per the EPMO office, all future projects shall comply with the statutory requirements of the IT projects. The constraints, and controls must be considered from the beginning of the inception of the projects to the completion and 5 years into the maintenance cycle.

Involvement of the assigned EPMO approved PM is to be sure that all phases of the projects adhere to the statutory requirements and reporting requirements of the State of North Carolina.

Approvals for such implementations of tolling infrastructure projects are subject to six (6) agencies for continual approval of the project and monitoring the continuing status.

Statewide IT Project Approvers:

- Enterprise Project Management Office (EPMO)
- Strategy & Architecture (SA)
- Office of State Budget and Management (OSBM)
- Office of the State Controller (OSC)
- State Chief Information Officer (SCIO)
- Senior Deputy State Chief Information Officer (SDSCIO)

Appendix E. BOS Overview and Extra Work Order Details

BOS Overview

The XEROX software product, Violation Enforcement Customer Service Toll Operations Reporting (VECTOR), is designed to handle the processing of lane transactions (ETC and video), provide customer service capability, handle financial transactions, perform reconciliation and revenue management, and produce system-wide reporting. The BOS will support account processing from any type of toll system, all electronic or with cash collection (not contemplated at this time), point-based tolling or a trip-based system.

The TCS also allows NCTA to provide service to customers via multiple channels including Web and interactive voice response (IVR). VECTOR supports sending customer notifications via multiple channels including mail, email and text messages. The North Carolina Turnpike Authority system allows for a fully integrated customer service solution and customer service center (CSC), and incorporating Siebel Customer Relationship Management (CRM).

The VECTOR BOS is divided into the multiple subsystems shown in the following table:

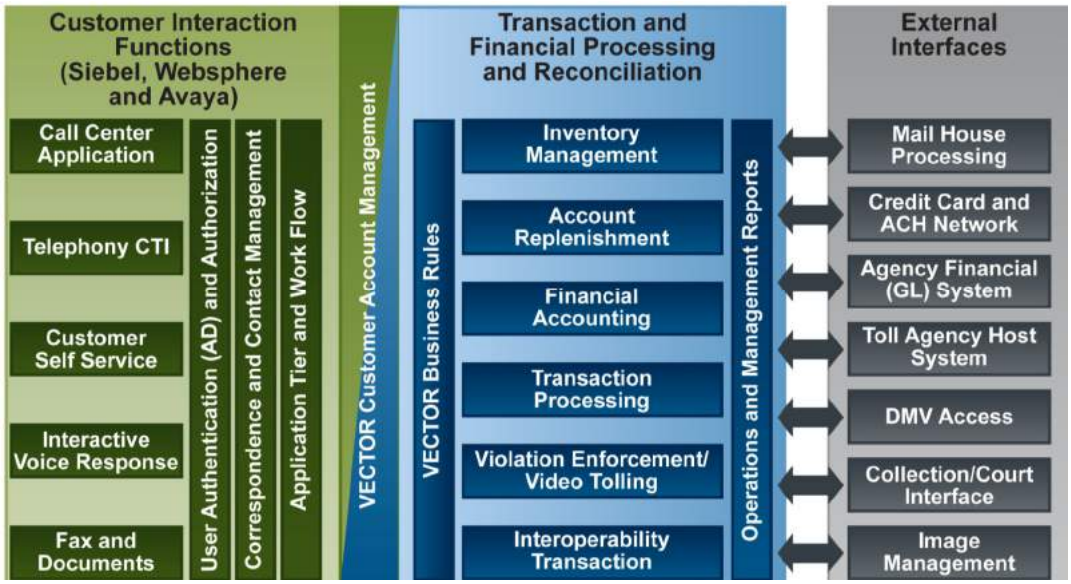
Subsystem	Functionality
Customer Account Management System (CAMS)	New patron account setup ETC (private, business/commercial, government and non-revenue), video toll (registered and unregistered) Account maintenance – full CRM services
Device Inventory Management System (DIMS)	Transponder order, tracking, warranty, history and maintenance; transponder distribution; transponder sale or leasing.
Financial Processing Management System (FPMS)	Accounting of all revenues [ETC, video toll, (registered and unregistered), non-toll, and other] Payments, adjustments, reversals, and settlements General Ledger (GL) and sub-ledger accounting
Violation & Video Enforcement Management System (VEMS)	Video tolls Invoicing, escalation fees/penalties, payments, administrative hearings and disputes Collections and department of motor vehicle (DMV)
Transaction Processing Management System (TPMS)	Pre-processing, validating toll fare and posting Host interface Interoperability processing Transaction reconciliation with host
System Administration Management System (SAMS)	VECTOR business policy configuration User roles, position management and access controls
Business Intelligence System (BIS)	Dashboards VECTOR suite of reports Ad-hoc query report management

Table E1: VECTOR Subsystems

The toll and video transaction processing modules manage the transaction data received from the lane, plaza through a roadside host, to process transactions from both Home and interoperable Away agencies. The transactions are handled through the reconciliation process. The primary functionality of this component includes the receipt of transactions and images from the RTCS and appropriately processing for toll revenue.

The Financial Processing Management System provides control for payment processing, updating accounts, and enables exception processing. VECTOR distinguishes between private and commercial accounts and performs the corresponding replenishment and account status update when a payment is initiated. NCTA business policies govern the management of customer accounts. Report sub-sections are operational reports, financial reports, transaction reports, and interoperability report specifications. VECTOR interfaces with many and varied external entities, providing NCTA with a single point of processing in the BOS. This will be the case with US 74 Express Lane transactions. The functional components within VECTOR and the external interfaces are illustrated in the figure below.

Figure E1: Functional Components & Interfaces of Back Office System



Extra Work Order Scope of Work to Support US 74 Express Lanes

The following outline addresses in detail the probable Scope of Work that XEROX will be required to address in their negotiated technical information and price proposal submittal. It is important to note that prior to negotiating the scope of work and pricing, NCTA/NCDOT will need to finalize system and business policies for US 74 Express Lanes and other planned managed lane projects as well. Programming modifications would be optimized for the future and will save time and effort when new project come online.

Key requirements and roles for the probable Scope of Work are:

System and Business Policies (NCTA)

Prior to commencing negotiations for probable modifications to the BOS, all new system and business rules that would affect US 74 toll transaction development in the lane need to be finalized. This would include:

- Class of vehicle allowed in the Express Lane
- Toll rate (where it is applied: in lane or at the BOS)
- What type of transactions, single point or trip (in future expansion), will be transmitted to the BOS?
- OCR requirements
- What appears on the customer's statement
- Determination of new transponder type:
  - Will the transponder have an occupancy declaration mode?
  - Will the transponder be recognized by interoperable agencies?
  - Need to specify all characteristics of the new transponder, including warranty information (similar information that is used for current transponders)
- What are the business policies for existing transponders when they are used in Express Lanes?

- What are the revenue reporting requirements for each new facility?
- Are any fees (late fees, processing fees, NSF fees, etc.) associated with accounts or invoices to be split between facilities and on what basis if they are?

Scope of Work (XEROX)

Within the Scope of Work requirements for probable modifications to the BOS, it will take a coordination of effort between NCTA and XEROX to successfully implement system modifications required by the addition of a new facility to the current operating structure.

- **Modifications Required - Transponder:**
  - New transponder type – This will have to be added to the list of transponder types that are available to the customer
  - Inventory management - Tracking inventory will now require additional location information with the addition of remote storefronts
  - Customer profile changes to handle this transponder
  - Transaction file layout changes to handle switch status
  - Display of status in toll history screens, potential on customer statement
  - Inventory reports and transaction reports – need to be changed to add the additional information
    - Store front inventory management
    - New store(s) in CRM
    - Physical inventory SOP's and security
  - Will the new declarable transponders follow the same TDM transponder prefixes?
  - Will they be used in non-toll scenarios (like the parking stickers?)

- **Modifications Required – Financial Accounting**
  - Additional use cases for financial reporting under specific roadways
  - New transaction codes to be determined
  - Single invoice to show transactions from all facilities with same escalation rules, requires receivables at facility level
  - Need to pull the transactions at a detailed transaction level.
  - Need to look at how to reflect the revenue.
  - Assume that these roadways will have different financial handling
  - Need to have additional revenue mapping within financial system
  - Need to look into the detail handling of revenue:
    - Identify exact transaction that is paid, dismissed or disputed
    - Treatment on revenue reconciliation with different NCTA and DOT GL accounts
    - Revenue accounts and receivable accounts
    - Reports to reflect revenue by roadway, aging and settlement period
    - NC Quick Pass pool account functionality
    - Single account prepaid balance
  - Determination of fee distribution (Late fees, processing fees, NSF fees, etc.) between additional facilities
    - How is the revenue going to be shared,
    - How will this translate to the mapping to the general ledger recognition of the revenues?
    - Will this be in or outside the tolling system for the NSF and other fees?
    - How would the revenue get moved to the right place?

When considering the above, it is also important to factor in the contractual requirements between NCDOT and the I-77HOT Lanes developer (Cintra) for revenue distribution for the I-77 Express Lanes.

- **Modifications Required – Transaction Processing**
  - Addition of facilities and communication to EZ-Pass
  - Plaza definitions includes description on statements – home/away (mail house)
  - Transaction processing rules
  - Frequency of transmission and method of data exchange (drop box)
  - Transmission of transaction data from US 74
    - File layout to comply with existing specification except for declarable transponder status
    - Cross lane reads, buffered transponder processing, duplicate checks, poaching rules
    - Any default logic and time between tolling points.
  - Any type of discount plans or promotion periods ($0 tolls in the initial rollouts)
  - Toll amount calculations
  - Reconciliation process that is in place with the I-77 developer and the other facilities.
  - How will the customer service center handle toll amount disputes?
  - How will the customer service center need to handle transactions?
  - What are the specific types of disputes that they will need to address?
  - Dynamic pricing and trips- when a customer calls the CSR, they will need to be able to access the details of the transactions.

- **Modifications Required – Video Image Processing**
  - Image Processing to follow Interface Control Document
  - Image file resolution and file size
  - Number of images and naming conventions (is it the same as Triangle Expressway otherwise there will be more changes in the system)
  - Color images – there should be no difference
  - OCR information- if no image review is required will the system receive plate number, state information?
  - OCR—will be performed similar to Triangle Expressway in back office
  - Timing of image availability for invoicing and CSR pull-up
    - Data exchange and frequency of image file exchanges
    - Image review and automation
    - OCR automation on the new roadways
    - OCR thresholds and impact on OCR reports
    - Image review application access

- **Modifications Required – Functional Areas**
  - Application changes
    - CSR application: training for the CSRs for new transponder types.
    - How to handle new financial transactions, receivables and adjustments
    - Financials - oldest transactions saved.
    - Apply payments to oldest transactions by roadways
    - Trip detail lookups and disputes
    - New toll history view with declarable transponders
  - Web changes
    - User documentation updates
    - Static changes required

        - Mobile web changes
    - User Agreements,
    - Tag Packaging,
        - PDFs on the web need to be adjusted.
    - New FAQ's and information regarding new facilities
    - Toll rate information
    - Details on toll activity regarding status of declarable transponders
    - IVR call tree modification
        - Static message changes

- **Modifications Required – Video Image Processing**
    - Integrity reports
    - Transaction reconciliation report
    - Financial reports
    - New roadway settlement report (for prepaid and post-paid revenue)
    - Revenue Reconciliation report (FIN 1001, 1002 and 1003)
    - OCR reporting.

- **Modifications Required – Infrastructure**
    - Network termination from additional toll facilities to NCTA equipment
    - Firewall definitions
    - Connectivity testing
    - Circuit termination (switches)
    - Storefront connectivity – Phones, back office etc.
    - Storage requirements – how large, will all come to back office which will make it more consistent, but storage size requirement will depend upon how they formulate the transaction
        - Dependent on Image size
        - Retention rules
        - Servers
    - Drop box for file exchange – need server adjustment for capacity here.
    - Server capacity for additional facility processing (image, OCR, etc.)
    - Licenses – If there are additional CSRs there needs to be new terminals and licensing.
        - Additional CSR and CTI licenses
        - Telephony licenses and expansion to Store front
    - PCI extended scope (new storefront)

As the project progresses, there will probably be additional items of modifications to the BOS that will need to be addressed. The above listing is not intended to be all inclusive, but rather to illustrate the breadth of impact US 74 Express Lanes will have on the existing BOS.