NC Capital Area Metropolitan Planning Organization

Western Wake Traffic Signal System Integration Study

Integration Guidebook

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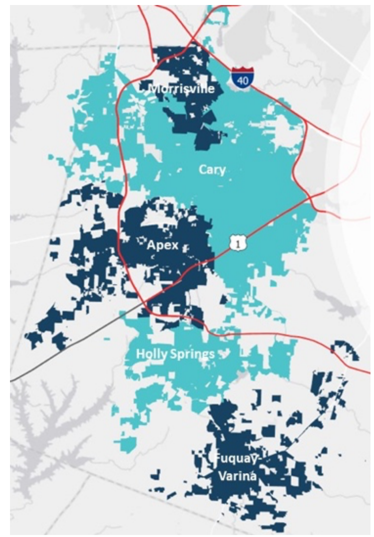
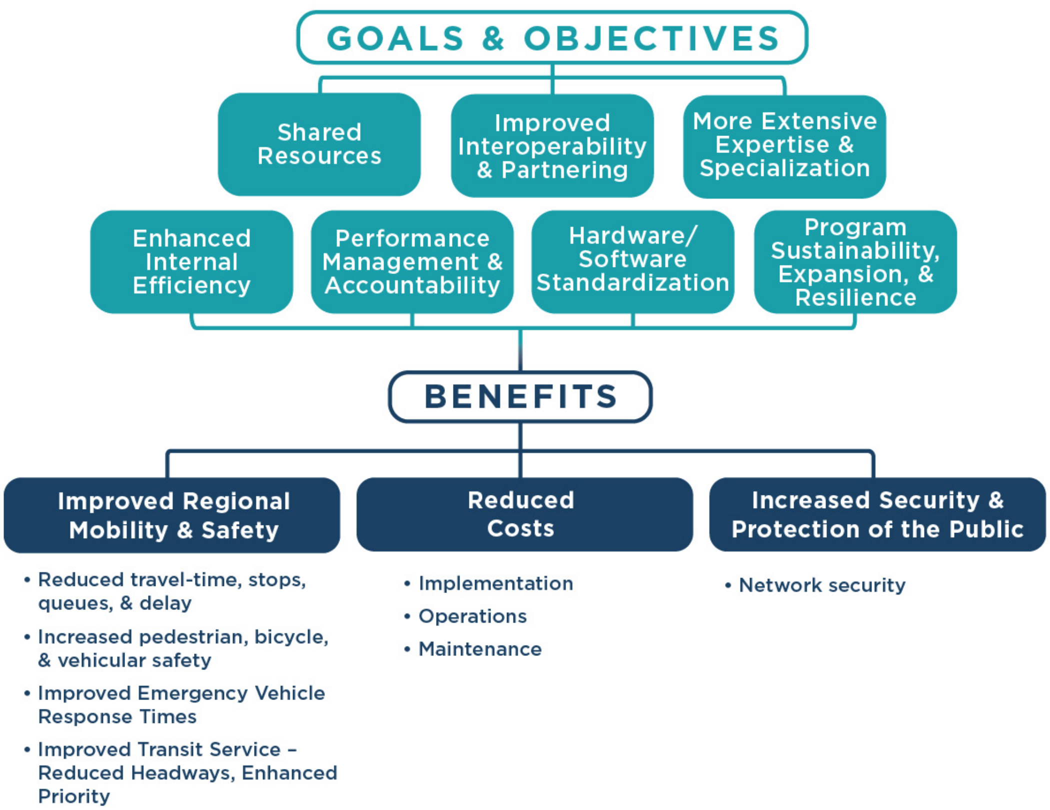
EXECUTIVE SUMMARY

Released in 2020, the Triangle Region Strategic Deployment Plan for Intelligent Transportation Systems (ITS) identified a goal for regionalized ITS systems, including coordinated signal systems. This Western Wake Traffic Signal System Integration Guidebook assesses the feasibility of a regional signal system in Western Wake County among the Towns of Apex, Cary, Fuquay-Varina, Holly Springs, and Morrisville. The goal of this project is to provide well-defined steps for integrating, operating, maintaining, and funding regionally integrated signal systems. The project seeks to meet the functional needs of each agency while providing a plan that is reproducible, flexible and allows for long-term sustainability in maintenance and operations.

A well-managed traffic signal system plays a key role in efficient operations of the system. Studies have demonstrated the benefits of succinct traffic signal system operations. In the Western Wake region, there are several towns in which the jurisdictional boundaries are almost woven together. Regional operations management and standardization will bolster the benefits that may be achieved by operations of separate traffic signal systems.



The Core Technical Team (CTT) for this study identified several overarching goals and objectives for regional standardization and operations. These goals and objectives translate directly to benefits of improved regional mobility and safety, reduced costs, and increased security and projection for the public. These benefits have been proven through similar signal system integration studies and related projects as detailed in FHWA's ITS Database.



NCDOT owns more than 9,500 signals across the state, and while many of those are operated and maintained by NCDOT Division staff, many still reside within municipalities that have built-up traffic signal expertise in-house. Smaller municipalities have traditionally benefited from the operations and maintenance support provided by NCDOT for traffic signals on state-owned streets. However, exceedingly high population growth and urban development are resulting in increased traffic volumes, congestion, and safety concerns. As growth demand warrants additional traffic signals, municipalities are finding the need to operate and maintain traffic signals on municipal-owned streets. Additionally, many towns have a growing desire for more management, oversight, and control of the traffic signal system within their towns.

Within the vicinity of the western Wake study, the Town of Cary is the only town currently operating a municipal traffic signal system. The towns of Cary and Morrisville operate multiple town-provided services through shared resources and this extends to the traffic signal system as well. The Town of Cary currently operates and maintains some of Morrisville's traffic signals. This guidebook looks at a phased plan to expand on the integration of these two town traffic signal systems.

The towns of Apex, Fuquay-Varina, and Holly Springs are beginning to see the need for traffic signal system management at varying degrees. Traffic congestion, safety, town-owned signals, and increased need for more intensive management and operations control will be some of the key factors driving each towns evaluation of pursuing a regional traffic signal system collaborative.

The Integration Guidebook essentially contains two plan elements:

1. A more granular Implementation and Operations & Maintenance (O&M) Plan for the towns of Cary and Morrisville, given their current level of integration.
2. A more high-level Implementation and O&M Plan for the Western Wake Region that is also meant to be reproducible throughout the Triangle Region.

Each of these plan elements, is followed by a prioritization plan that considers the current status of infrastructure and regional collaboration. For example, near-term recommendations for the Cary and Morrisville integration may include incorporation of additional Morrisville signals into the Cary signal system or adding cameras to Morrisville signal installations since those Towns have existing agreements and cost sharing processes in place. However near-term recommendations for the larger Western Wake Region are geared more toward identifying which agencies will be part of a regional system collaborative and establishing a steering committee and regional host.

The near, mid, and long-term recommendations for the integration of Cary and Morrisville traffic signals include the following:

Near-Term Recommendations	
1	Integrate additional Town of Morrisville Traffic signals into the Town of Cary signal system network
2	Add Town of Cary operations and maintenance staff to support organic growth of the Cary signal infrastructure and integration of all signals in Morrisville
3	Dedicate traffic signal and maintenance/storage space in the new Town of Morrisville Public Works Facility, which is currently under design.
4	Conduct a regional communications infrastructure study
5	Add cameras to Morrisville intersections based on operational needs
6	Update and execute agreements between Town of Cary and Town of Morrisville for the on-going shared resources and management of signals including: a. Collaborate between the two agencies to ensure network security. b. Define roles and responsibilities, as they relate to the system, between varying members of the Town of Cary and Town of Morrisville agencies. c. Develop performance requirements for availability and reliability for fiber infrastructure. d. Develop performance requirements for traffic signal operations

Mid-Term Recommendations	
7	Redundant, path-diverse C2C connection between Cary and Morrisville facilities to enable Morrisville staff to view CCTV cameras and system operations.
8	Provide user access for Fire Departments, Police, and Emergency Departments based on operational need
9	Establish traffic signal maintenance and storage space in new Town of Morrisville Public Works Facility once construction is completed.
10	Begin implementation of technologies used in Cary to the Morrisville signals where appropriate (i.e., TSP, EVP)
11	Implement ATSPM at all traffic signals along key corridors in Cary and Morrisville
12	Evaluate potential ICM corridor along I-40, NC 54, Aviation Parkway, Airport Boulevard, I-540, NC 147, and Harrison Avenue
13	Establish communications connectivity to neighboring jurisdictions (Durham and Raleigh)
14	Perform a transportation network-specific cyber security assessment

Long-Term Recommendations	
15	Implement ICM technologies along I-40 parallel arterials and cross-connecting interchange arterials
16	Build-out fiber connections to new or peripheral signals within Cary and Morrisville
17	Implement ATSPM at all remaining traffic signals in Cary and Morrisville
18	Establish pilot program for testing of new technologies as they become available throughout the system
19	Consider Smart City connectivity and other advanced technologies when planning and investing in the communication networks
20	Add Town of Cary operations and maintenance staff to support organic growth of the Cary signal infrastructure and integration of additional signals in Morrisville (as needed)
21	Provide connectivity to allow for electronic signal lab capabilities in new Town of Morrisville Public Works Facility

The near, mid, and long-term recommendations for the regional system collaborative include the following:

Near-Term Recommendations	
1	Each agency to evaluate potential participation in a regional system. Determine which agencies will be a part of the regional system.
2	Form a steering committee/oversight committee for the proposed regional system
3	Determine who the Regional Host should be for the regional signal system
4	Develop agreements between agencies for on-going shared resources and management of signals including: A. Define roles, responsibilities, data sharing requirements, and cost-sharing responsibilities as they relate to the system. B. Develop performance requirements for availability, reliability, and security of fiber infrastructure. C. Develop performance requirements for traffic signal operations and maintenance.
5	Begin requests for capital expenditures, new employee positions, and annual operating and maintenance expenses
6	Construct the proposed Fuquay-Varina signal system
7	Conduct a regional communications infrastructure study

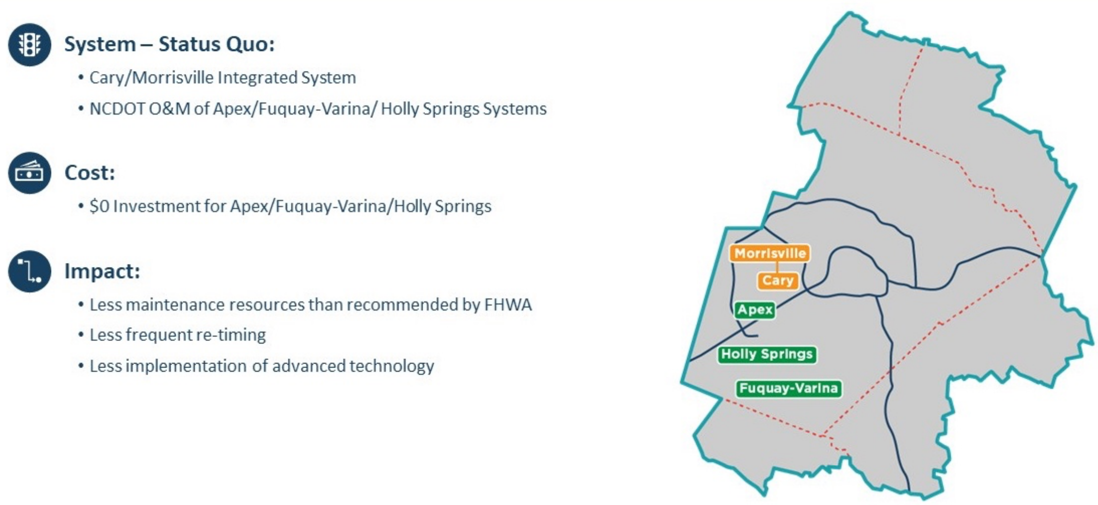
Mid-Term Recommendations	
8	Add cameras to individual intersections based on operational needs.
9	Develop regional standards for signal system technology
10	Design the Apex and Holly Springs portions of the regional system
11	Design and construct the regional TMC and signal maintenance facilities
12	Establish a C2C communications link between the regional TMC and the STOC
13	Elevate operations and maintenance of the regional system to increased LOS
14	Evaluate connected vehicle, EVP, and TSP technologies along key arterials within the regional system
15	Employ management of a network monitoring software to enable proactive and responsive network maintenance as a regional collaborative

Long-Term Recommendations	
16	Construct the Apex and Holly Springs portions of the proposed regional system and integrate them into a regional system with the previously constructed Fuquay-Varina signal system
17	Light-up fiber optic cable connections along the proposed regional communication ring to provide path-diverse, redundant, regional connectivity among municipalities
18	Accommodate access for all agencies within the regional network such that each can view and monitor system performance.
19	Deploy TSP, EVP, and CV Technologies throughout the system
20	Deploy ATSPM throughout the region
21	Elevate operation and maintenance of the regional system from level-of-service perspective for opportunities of enhanced traffic operations
22	ACHIEVE CONNECTIVITY BETWEEN THE REGIONAL SYSTEM AND THE NEARBY CITY OF RALEIGH AND TOWN OF GARNER SIGNAL SYSTEMS

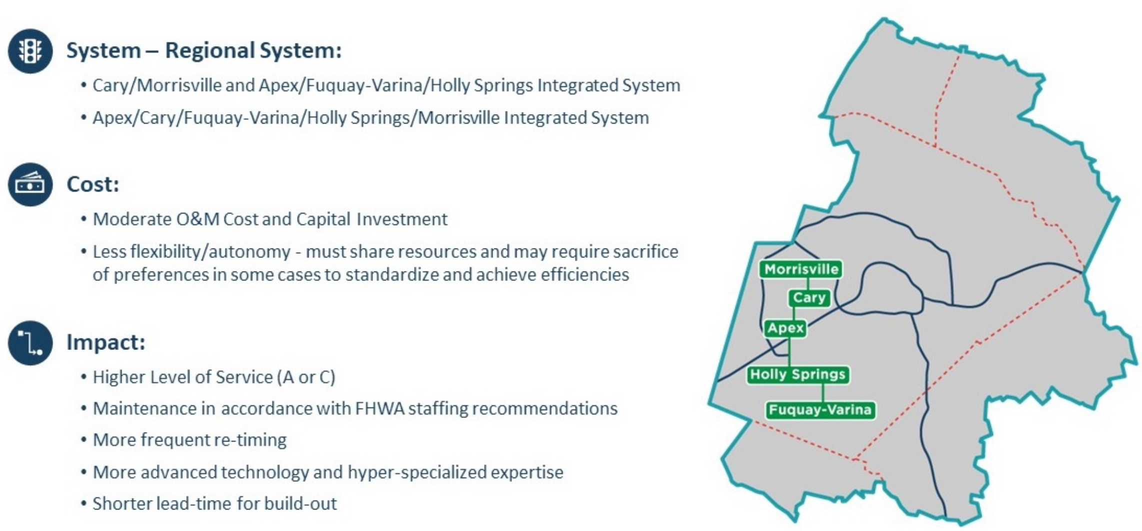
These recommendations have been spread over a ten-year horizon, in-part due to the funding required for many of these implementations. While funding sources and grants are available for transportation system enhancements, the competitive nature for many of these sources can be limiting to smaller agencies. A regional system would enhance the opportunity for more collaborative and effective grant proposals with improved scoring, and faster funding for each of the regional participants. Throughout the recommendations chapter, each recommendations identifies the cost considerations, potential funding source alignment, and how the recommendation supports the overall goals and objectives.

Understanding that each agency's evaluation of joining a collaborative regional system will be individualized, there are bottom-line cost benefits to the region operating as one system. If you were to consider the options laid out to be:

Alternate #1 - Operate as Status Quo: where Cary and Morrisville maintain their current level of integration and Apex, Fuquay-Varina, and Holly Springs remain as is with some level of NCDOT closed loop system operations.



Alternate #2 - Operate as a Regional System Alternative: Where there are two options – Cary/Morrisville are integrated and Apex/Fuquay-Varina/Holly Spring are integrated.



Alternate #3 - Operate as Separate Signal System: where each agency builds expertise in-house and operates their own traffic signal system independently.

System – 5 Separate Signal Systems:

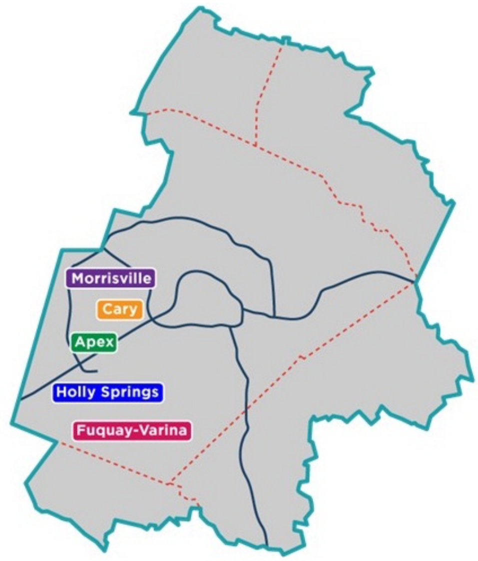
- Apex/Cary/Fuquay-Varina/Holly Springs/Morrisville Separate Systems

Cost:

- Higher O&M Cost
- Extensively Higher Capital Investment
- Longer lead-time for build-out
- Less efficiency and specialized expertise for the region

Impact:

- Higher Level of Service (A or C)
- Maintenance in accordance with FHWA staffing recommendations
- More frequent re-timing
- More advanced technology



The program costs for each of these system alternatives has been evaluated throughout this study. The table below summarizes the cost comparisons of these alternatives. Where the 1-Regional System is the most cost effective and the 2-system and 5-system alternatives are compared against it.

Alternative	Total Annual O&M Cost	Annual O&M Cost Per Signal	% Increase in O&M Costs	Implementation Cost	% Increase in Implementation Cost	Regional 10-Year Cost
2 Regional Systems	$3,182,288	$5,730	5%	$11,920,000	12%	$43,742,880
1 Regional System	$3,070,224	$5,450	0%	$10,620,000	0%	$41,322,238
5 Separate Systems	$3,462,927	$6,410	18%	$16,500,000	55%	$51,129,274

For each agency to operate independently is the most expensive alternative, given the capital outlay that would be needed and the build-up of expertise for each agency. Operating two regional systems is not the most efficient, but is still much more cost effective than the five separate systems. In summary, the Western Wake Traffic Signal System Integration Study proves that the implementation of a regional signal system among the towns of Apex, Cary, Fuquay-Varina, Holly Springs, and Morrisville would result in the most efficient and effective alternative for Western Wake County.

Chapter 02

EXISTING TECHNOLOGY, INFRASTRUCTURE, & MANAGEMENT STRATEGY EVALUATION

Existing traffic signal technology, infrastructure, and management strategies vary from location to location. A community's history of implementation, growth, geography, density, commuter patterns, funding, and staffing resources all play a role in the way a transportation system is managed. The communities throughout Western Wake County provide a snapshot of the varying degrees of operation and use of technologies from town to town. Whether an agency already has an extensive signal system network or is just beginning to see the need for signal connectivity and hands-on management (and anywhere in between), having a documented implementation plan and process will aid in successful implementation. The first step is establishing a baseline by documenting existing conditions.

Chapter 2 will describe the existing field infrastructure, software systems, traffic management center facilities, user access, and existing operations and maintenance of each agency.

2.1 FIELD INFRASTRUCTURE

TRAFFIC SIGNAL CABINET CONFIGURATION

Every traffic signal is operated by a computerized system that resides in a traffic signal cabinet at each intersection. The computerized system receives inputs from detectors that enables it to discern how to respond based on pre-programmed signal plans. The system then uses electrical impulses to change the traffic lights in accordance with those plans and responses. There are notable differences among the traffic signal cabinets in Western Wake County, with NCDOT traffic signal cabinets having a typical configuration and Town of Cary traffic signal cabinets having another. This section provides a detailed summary and comparison of the existing traffic signal cabinet configurations.

NCDOT has a statewide standard for traffic signal cabinet configuration. A typical NCDOT traffic signal cabinet includes:

- 2070E controller with Oasis software version 3.03.61E and OS-9 operating system
- 2070-1E CPU Module
- 332A base-mounted (preferred) and 336S pole-mounted controller cabinets
- EDI 2018ECL-NC v0159 conflict monitor
- Rack-mounted fiber-optic interconnect center (i.e., splice center) (1 rack unit)
- Rack-mounted self/drawer (1 rack unit)
- Fiber optic transceiver (drop and repeat)
- Two-channel detector card
- Auxiliary output file(s) for flashing yellow arrow locations
- Model 200 load switches, Model 242 AC isolator, Model 242 DC isolators, Model 204 flasher, and flash transfer relays
- Telephone drop with dial-up modem or wireless broadband modem (closed-loop system master locations and some isolated signals)
- 900 MHz spread spectrum radios (wireless links only)

Type 2070E controllers manufactured by McCain and by Naztec are currently listed on the NCDOT ITS and Signals Qualified Product List (QPL). The 2070 controllers in the study area were installed over many years and under multiple projects; as such, there are 2070 controllers from a variety of manufacturers currently in use in Western Wake County. Some cabinets house 2070E controllers by other manufacturers such as Safetran, and other cabinets house legacy 2070L controllers with 2070-1B CPU modules by manufacturers such as Siemens.

Fiber-optic transceivers deployed in Western Wake County include International Fiber Systems (IFS) D9130 (non-self-healing) and Meridian Technologies PX2300M-2ST (self-healing ring). Most 900 MHz spread spectrum radios in use are Encom Model 5200 radios, but there are some Intuicom Communicator II radios in use as well. None of the closed-loop systems use Ethernet communications at the present time.

Town of Cary typical NEMA TS 2 cabinet inventory includes:

- Econolite or Safetran 2070LX controller with ASC/3-2070 software version 32.67.30 and Linux operating system
- 2070-1C CPU module
- Econolite or EDI MMU2-16LEip (conflict monitor)
- EDI LMD622t detector cards rack mount (222 will not work in TS 2)
- Econolite autoscope vision system (preferred if video detection required)
- Cisco IE-3300 Ethernet switch
- Polara audible pedestrian system (preferred if required)
- Fiber-optic interconnect center
- Connected vehicle roadside units in select locations
- Opticom Model 711 or 722 detectors
- Opticom Model 762 or 764 phase selector
- Q series AXIS CCTV camera
- Load switches, BIU, flasher, flash transfer relays

Figure 2.1: 2070 controller with MMU in NEMA TS 2 cabinet

The Town of Cary is evaluating Automated Traffic Signal Performance Measures (ATSPM) equipment at four locations:

- Davis Drive and Morrisville Parkway
- Davis Drive and Morrisville Market Entrance
- Davis Drive and Morrisville Carpenter Road
- Davis Drive and Lake Grove Blvd

Since signals within the town limits of Apex, Holly Springs, and Morrisville have been incorporated into the Cary signal system, those signals generally comply with the above Town of Cary cabinet setup. However, the controller type may vary at some non-Cary intersections such as NC 55 (Williams Street) at Jenks Road/Old Jenks Road in Apex, where there is a 2070E controller rather than a Cary-standard 2070LX.

There are some notable differences between the controllers and cabinets within the Cary signal system and those located throughout the other communities in Western Wake County.

Figure 2.2: 2070 controller with CMU in 332 cabinet

1. **Controller Cabinet Type** – One of the more visible differences between signalized intersections in the Cary signal system and those in other parts of Western Wake County is the controller cabinet. Cary uses a NEMA TS 2 base-mounted cabinet instead of the Caltrans-style Type 332A base-mounted cabinet used at all other locations.

2. **Controller Type and Controller Software** – The Town of Cary uses 2070 LX controllers with ASC/3 software whereas the majority of the remaining signals in Western Wake County have either 2070E or 2070L controllers with Oasis software. Oasis runs on the OS 9 operating system, so it cannot be installed on a 2070LX controller, which uses a Linux operating system. The 2070LX controller is equipped with the 2070-1C CPU module; its increased processing power makes it conducive to some connected vehicle applications. The 2070E comes with the 2070-1E CPU module but can be outfitted with a 2070-1C in lieu of the standard 2070-1E CPU. NCDOT has often found it to be more cost effective to replace the entire controller rather than retrofit an existing 2070E controller with a 2070-1C CPU module. The 2070L controller has a 2070-1B CPU module and cannot accommodate a 2070-1C CPU module.

3. **Signal Monitor Type** – The Town of Cary uses malfunction management units (MMUs) based upon the NEMA TS 2 Standard whereas all other traffic signals in Western Wake County use conflict monitor units (CMUs). Both CMUs and MMUs perform a highly similar, critical safety function in monitoring the signal for problems such as improper and conflicting signals and improper operating voltages. However, the MMU provides broader fault coverage than a traditional CMU and provides monitoring redundancy. With an MMU, both MMU and the controller share the task of monitoring for problems and putting the signal in flash. The MMU is in constant communications with the controller via a high-speed SDLC serial bus.

4. **Communications** – The Cary signal system uses Ethernet communications and Cisco IE3300 Ethernet switches. The Town of Holly Springs has plans to build an Ethernet communications system but does not plan to utilize Cisco network hardware due to cost and compatibility concerns. The NCDOT closed-loop systems outside of Cary use traditional serial fiber-optic communications with fiber-optic transceivers. Although the legacy 2070E controllers in the study area can accommodate Ethernet communications, the legacy 2070L controllers cannot. In addition, a legacy EDI 2018ECL-NC conflict monitor does not have an Ethernet port. An EDI 2018ECLip-NC conflict monitor is required to connect the conflict monitor to an Ethernet switch. NCDOT has also adopted Ethernet communications for all new closed-loop systems and will be migrating all systems over in the future.

COMMUNICATIONS INFRASTRUCTURE

A signalized intersection will operate independent of a communications link to other signals along a corridor or to a control center. However, the efficiency of traffic management is significantly improved by establishing a communications network between signals. The most reliable communications link is achieved through fiber-optic networks. Wireless or 4G communication are also viable options for certain scenarios but have several drawbacks such as reduced bandwidth, reduced reliability, long-term maintenance requirements, and ongoing operating costs.

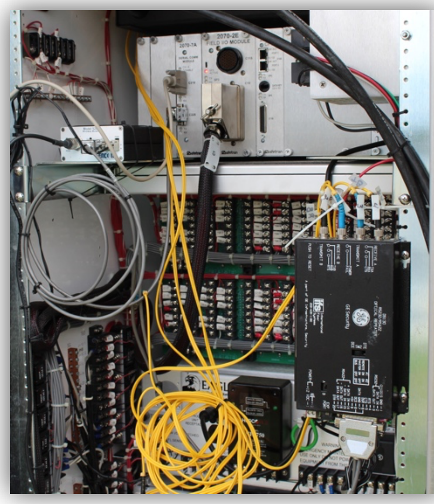


Figure 2.3: Fiber-optic transceiver (lower right) and 900 MHz radio (upper left)

Within Western Wake County, there are several closed-loop systems where communication has been established between signals along a corridor to improve the coordination of the signals. There is also a substantial fiber-optic network in both Cary and Holly Springs, which provides connectivity to many signalized intersections and ITS devices. Municipalities' approaches to communications infrastructure can be summarized as one of the following, in increasing order of complexity.

- Isolated Traffic Signals: signals that are not connected to a central system and are not coordinated with any other nearby signals.
- NCDOT Closed-Loop System: localized connectivity via a combination of a data connection and either fiber-optic cable or wireless communication for a specific corridor and/or group of signals. Could be in either an urban or rural environment.
- Municipal Traffic Signal System: primarily fiber-optic or wireless connectivity among most signals within the municipal boundary and controlled from a centralized system in a Town facility.

Figure 2.4: Yagi antenna for 900 MHz wireless communications

Table 2.1 below shows the communication infrastructure types used in each municipality in Western Wake County.

Table 2.1: Communications Infrastructure by Town

	Isolated Traffic Signals	NCDOT Closed-Loop System	Municipal Traffic Signal System
Apex	✓	✓	
Cary	✓		✓
Fuquay-Varina	✓	✓	
Holly Springs	✓	✓	
Morrisville	✓	✓	

Figure 2.5: Western Wake Existing Signal System Infrastructure

Western Wake Existing Signal System Infrastructure

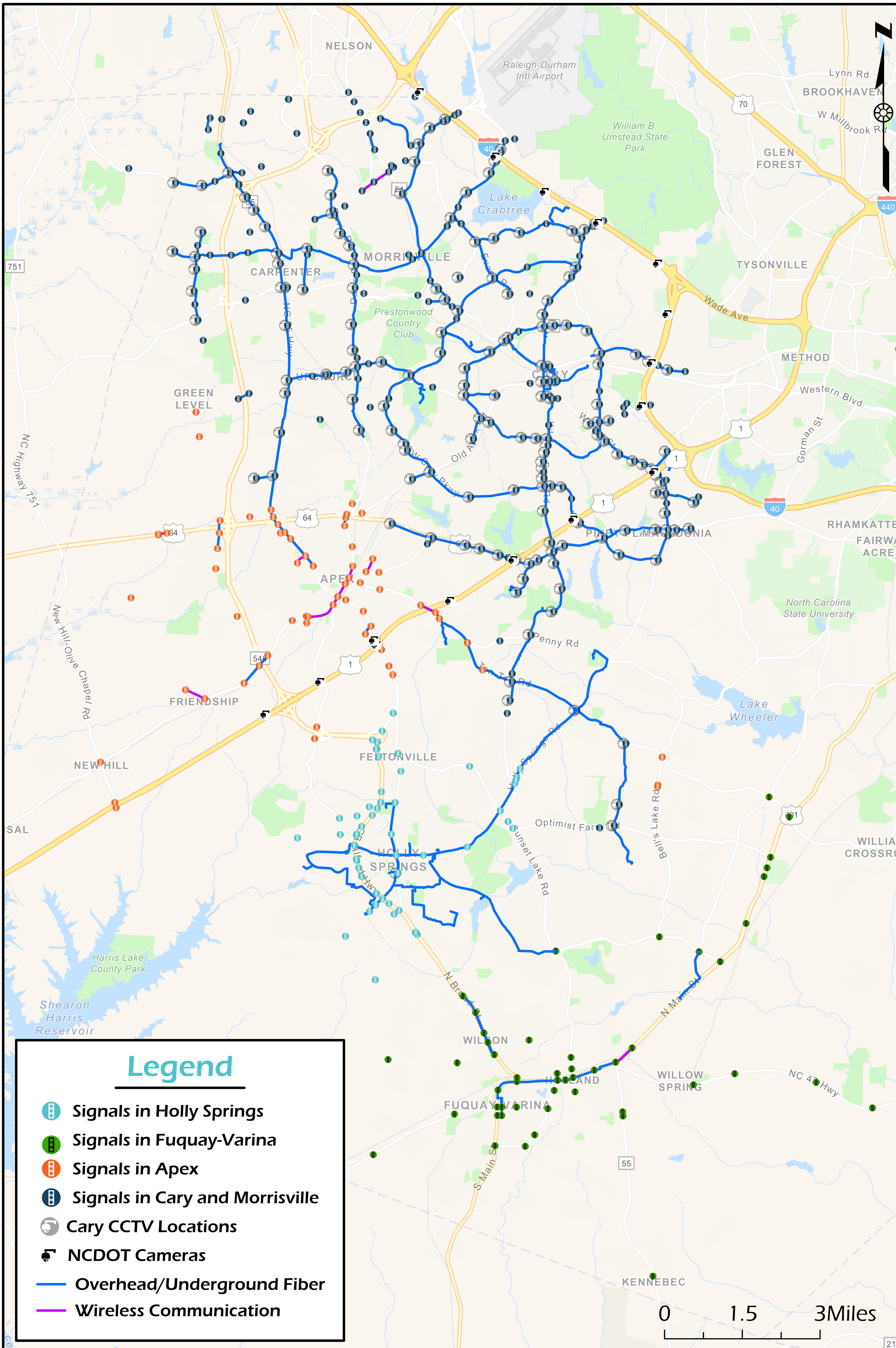


Table 2.2 identifies the number of signalized intersections within each municipality's jurisdictional boundary and details their communications media, if any.

Table 2.2: Signalized Intersections and Communication Type by Agency

Municipality	Total # Signalized Intersections	Signals Communicating via Fiber-Optic	Signals Communicating via Wireless	Maintained or Part of Another System
Town of Apex	72	8	10	6 – Cary System All others – NCDOT
Town of Cary	195	195	0	All signals – Cary
Town of Fuquay-Varina	50	14 39 – Future Signal System	1	2 – Garner System All others – NCDOT
Town of Holly Springs	57	21	6	1 – Cary System All others – NCDOT
Town of Morrisville	43	25	3	19 – Cary System All others – NCDOT

Figures 2.6 - 2.9 provide a close-up view of each Town's signals and communication links. The towns of Cary and Morrisville have been combined on a single map given the infrastructure sharing already in place.

Figure 2.6: Town of Apex Existing Signal System Infrastructure

Town of Apex Existing Signal System Infrastructure

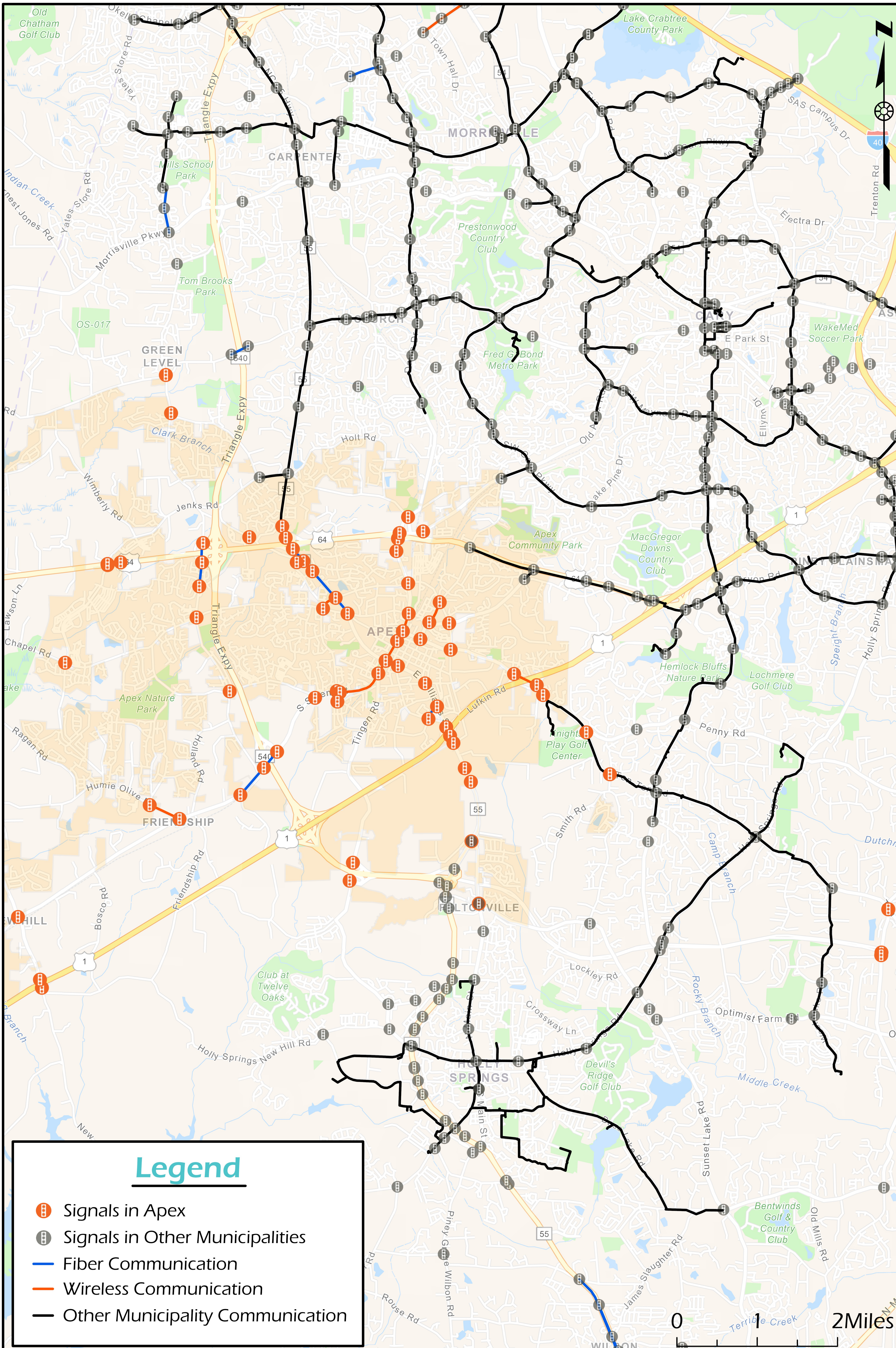


Figure 2.7: Towns of Cary and Morrisville Existing Signal System Infrastructure

Towns of Cary & Morrisville Existing Signal System Infrastructure

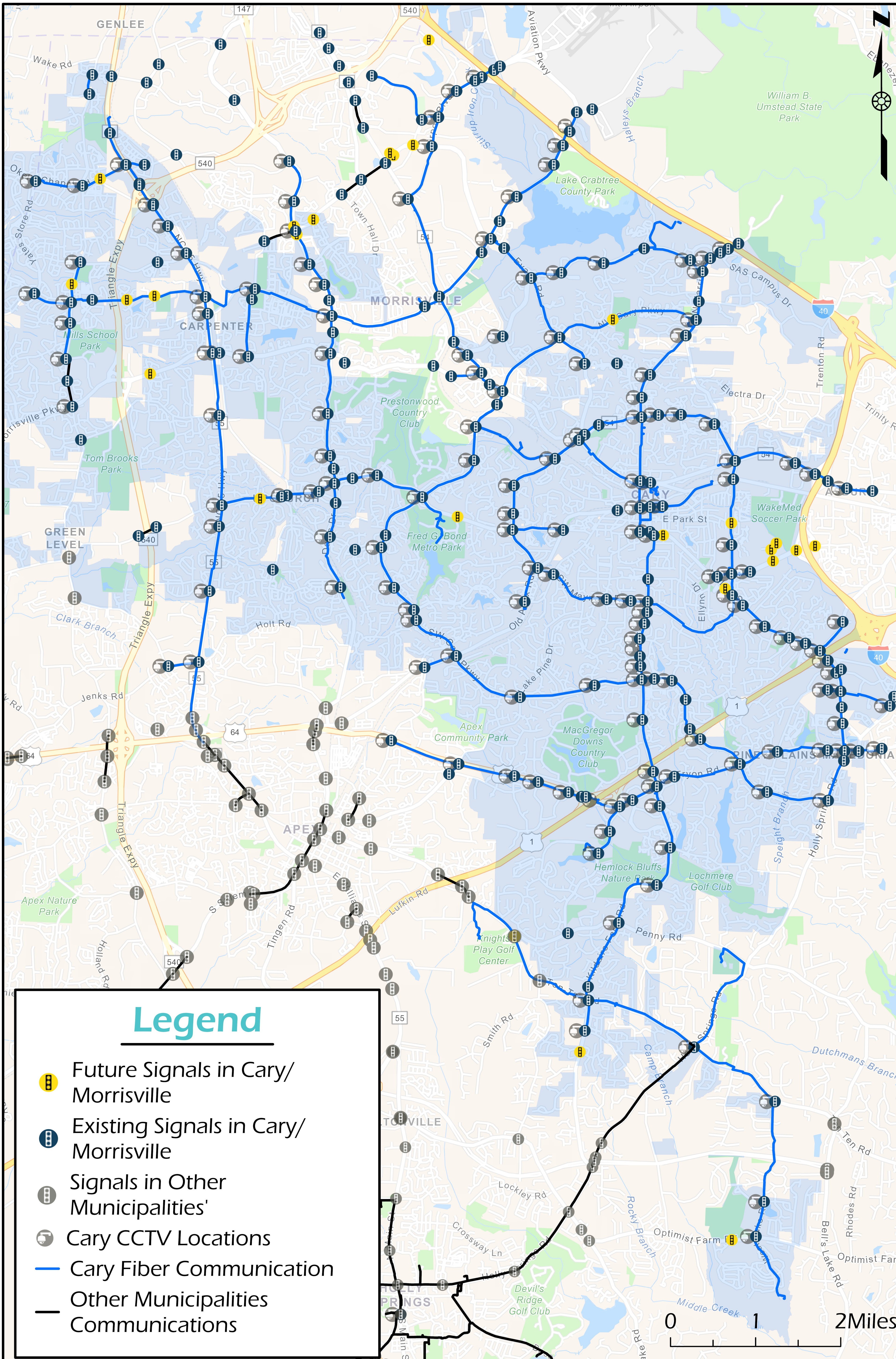


Figure 2.8: Town of Fuquay-Varina Existing Signal System Infrastructure

Town of Fuquay-Varina Existing Signal System Infrastructure

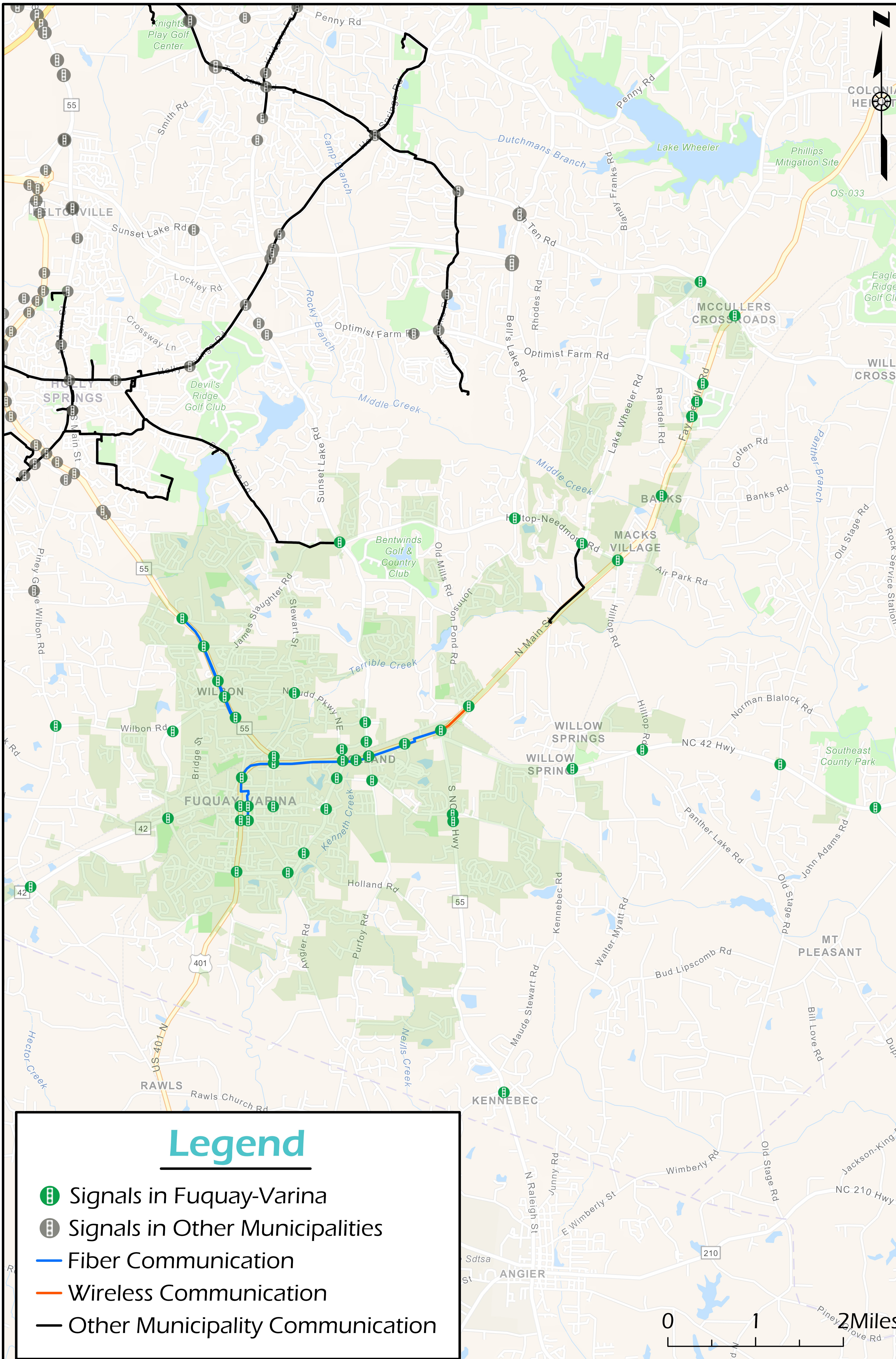
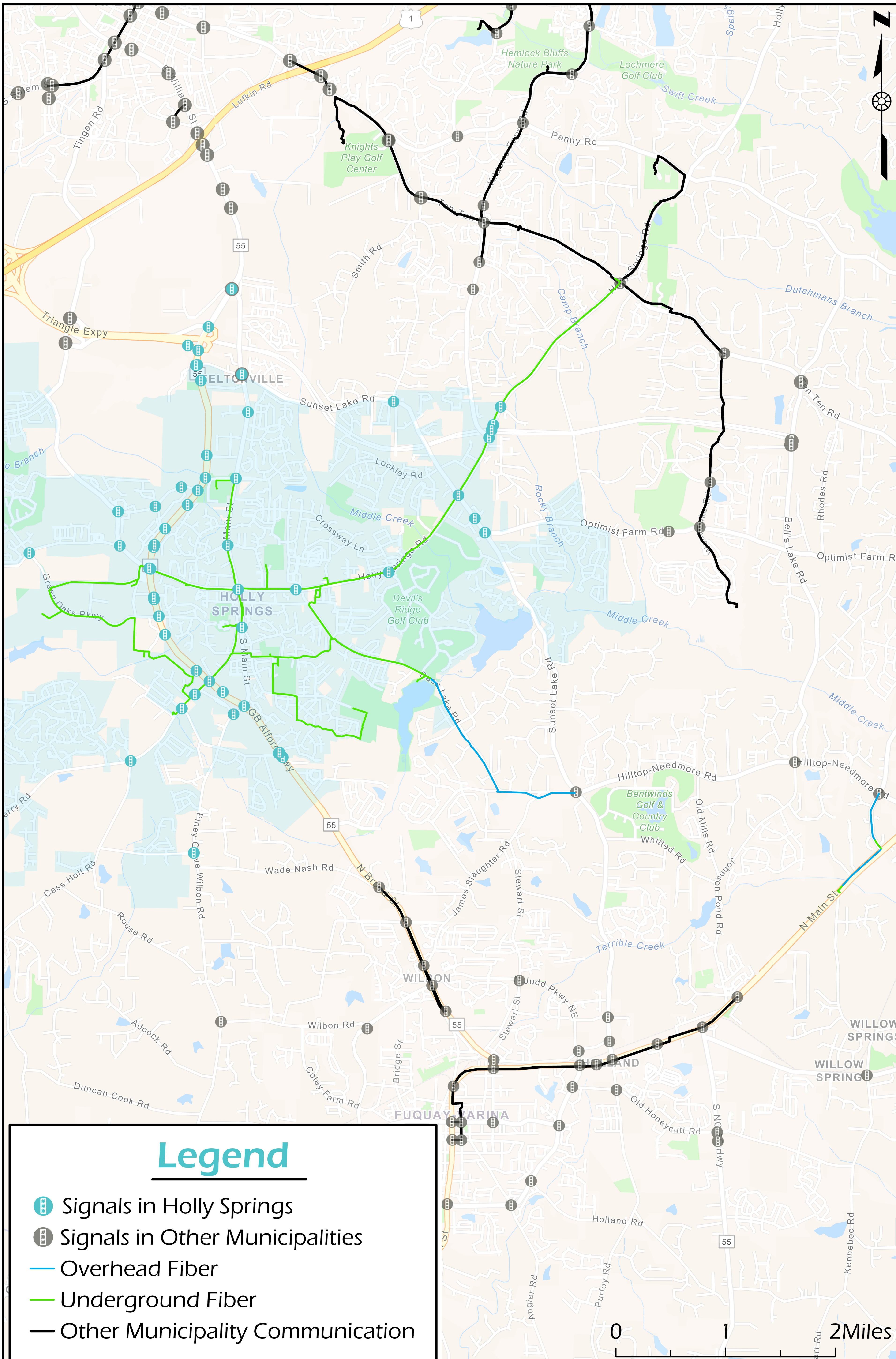


Figure 2.9: Town of Holly Springs Existing Signal System Infrastructure

Town of Holly Springs Existing Signal System Infrastructure



AGENCY STANDARDS

NCDOT maintains published standard specifications accessible on the NCDOT webpage. The current relevant versions for this study are the *2018 Standard Specification for Roads and Structures* and the *Signals and Intelligent Transportation Systems Project Special* Provisions, Version 18.6. All NCDOT signal and ITS designs comply with these standards. As agencies have increased their staffing and expertise, there may be additional or more specific requirements that would enable agencies to operate and maintain infrastructure more easily. As such, some agencies have identified additional or alternate standards for agency infrastructure.

Apex-Specific Standards

The Town of Apex follows NCDOT special provisions for all signal locations except those currently maintained by the Town of Cary—those signals are set to Town of Cary standards.

Cary-Specific Standards

The Town of Cary has identified the following Town standards that differ from NCDOT:

- Monocurve mast arms are the default structure type.
  - Metal strain poles are considered when mast arm lengths exceed 65'.
  - Mast arms and poles are required to be architectural in downtown Cary.
- CCTV cameras are provided at all new installations and added to existing locations when modifications are performed.
  - Axis digital cameras are required, and Cary updates the model type in accordance with Axis product changes.
- Communication is achieved via IP/Ethernet fiber-optic cable connections:
  - Each traffic signal must be integrated with the Traffic Operations Center (TOC) ATMS.
  - IP switches must be provided and installed as a part of any new installation.
  - Cary Marketing & Information Technology (MIT) Department configures all switches.
  - Expansion of existing fiber-optic network is required of all new installations.
- Cabinets are required to be NEMA TS 2.
- Controllers are required to use ASC3 local software with 1C modules.
- Combination meter bases are required at all new installations.
- Right-of-way must be provided on all approaches of an intersection to allow for maintenance of the cabinet, poles, and detection devices.
- Signal heads with Flashing Yellow Arrows (FYA) are required for all left-turn movements.
  - Time-of-Day (TOD) traffic signal plans are required for all locations with four-section FYAs.
- Pedestrian accommodations must be provided if pedestrian facilities are present.
  - Leading Pedestrian Interval (LPI) programming is required for new pedestrian crossings.
  - Accessible Pedestrian Signals (APS) are provided.
  - R10-15 (Turning Vehicle Yield to Pedestrian) signs are required for approaches with noted pedestrian crossings.
- W3-3 (Signal Ahead) signs are required in advance of the intersection for all approaches.
- Overhead street signs are to be provided with the following requirements and limitations:
  - Standard 18" green w/white border
  - 12" capital letters
  - 9" lower case letters
  - Not to exceed 96"

Figure 2.10: R10-15 Turning Vehicle Yield to Pedestrian

Fuquay-Varina-Specific Standards

The Town of Fuquay-Varina follows NCDOT special provisions for all signal locations.

Holly Springs-Specific Standards

The Town of Holly Springs follows NCDOT specifications for all locations except the one signal that is currently maintained by the Town of Cary. The signal at Main Street and Ballentine Street is set to the Town of Cary standards for their ease of operations and maintenance.

Morrisville-Specific Standards

The Town of Morrisville follows NCDOT specifications for all locations except the signals currently under agreement for operations and maintenance by the Town of Cary. These signals are set to the Town of Cary standards.

2.2 SOFTWARE SYSTEMS

As mentioned previously, each traffic signal is managed by a controller within the cabinet at each intersection. This controller is computerized and has a local software element (called firmware) that enables all aspects of traffic signal timing plans and coordination plans to be programmed locally into the controller. This enables the traffic signal to function whether a communication link to the traffic management center is present or not.

Centralized traffic signal system software typically resides on a server at the traffic management center or at a municipal data center. The centralized traffic signal system software communicates with each traffic signal controller over the fiber-optic cable network and enables synchronization of traffic signal plans, signal timing analytics, geographic displays of timing data in real time, maintenance analytics, and many other features that facilitate more effective operations and maintenance of the system.

CCTV systems enable users with appropriate access to view traffic conditions. The cameras deployed at intersections have pan, tilt, and zoom capabilities such that users can move the camera around and zoom to the appropriate viewshed to enable effective traffic operations response and evaluation.

This section provides further details about traffic signal firmware, central traffic signal system software, municipal managed CCTVs, and ancillary software elements used for advanced operations and maintenance of the systems.

TRAFFIC SIGNAL FIRMWARE

Traffic signals within the Cary Signal System use Econolite's ASC/3-2070 local controller firmware while all other signals in the study area use Econolite's Oasis local controller firmware. Econolite retired Oasis in 2013 and it is no longer available for purchase. It is still in use throughout North Carolina due to a statewide licensing agreement between NCDOT and Econolite. However, Oasis can only be used on 2070E (see **Figure 2.**) and 2070L controllers with their OS9 operating system; it cannot be used on the Linux-based 2070LX controllers. However, all the previously described controllers and operating systems can be connected to a central traffic signal software system.

Figure 2.11: Safetran 2070E Controller

Econolite's newest version of 2070 firmware is called EOS and has been deployed in a few locations outside of the study area, such as Charlotte, NC. While Econolite has transitioned all development activities towards EOS, the ASC/3-2070 firmware is still available and supported. Since about 2017, NCDOT has been using the ASC/3-2070 firmware when they construct new metropolitan signal systems and upgrade existing systems.

For integration of the Western Wake region, a key consideration will be transition of traffic signal firmware to a standard configuration that enables integration with central traffic signal system software.

CENTRAL TRAFFIC SIGNAL SYSTEM SOFTWARE

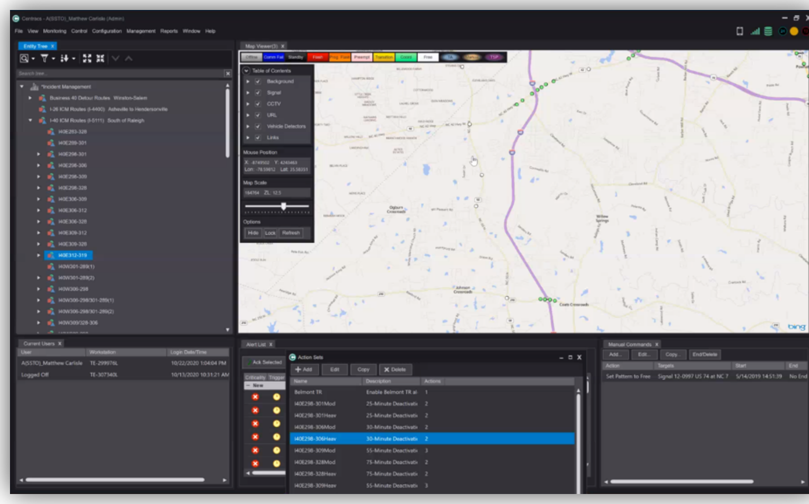


Figure 2.12: Econolite's CENTRACS ATMS

NCDOT uses Econolite's TransLink 32 closed-loop software to operate its closed loop signal systems under a statewide licensing agreement with Econolite for TransLink 32. Econolite retired this legacy software in 2007 and no longer supports it. Translink 32 is not a central traffic signal system software, but rather a tool for configuring the controller database and uploading/downloading the database to the controller. NCDOT also has a statewide Econolite CENTRACS ATMS software for management of controllers with ASC/3 firmware. As mentioned previously, NCDOT is deploying ASC/3 with CENTRACS connectivity for all new systems, such as the upcoming Morrisville, Fuquay-Varina, and Apex signal system projects. However, all NCDOT-maintained signals in the study area currently use Oasis firmware and the TransLink 32 database management software for central management.

The Town of Cary uses Econolite's CENTRACS ATMS (see **Figure 2.12**) software to control all signals within the Cary signal system. CENTRACS ATMS is used to operate several municipal signals systems throughout North Carolina.

MUNICIPAL-MANAGED CCTVS

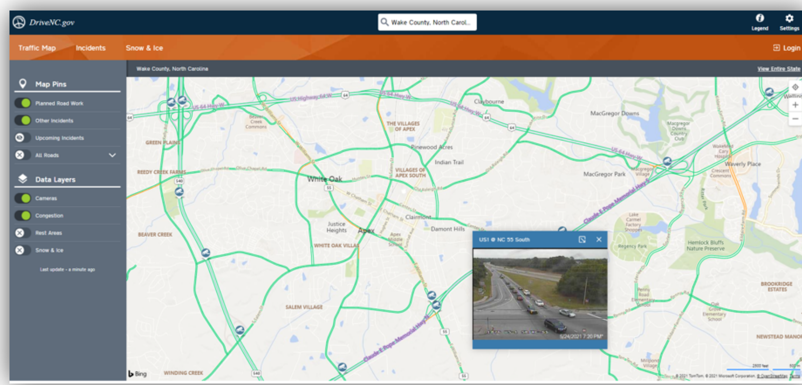


Figure 2.13: US 1 Ramp and NC 55 on NCDOT's DriveNC.gov Website

Municipal-managed Closed-Circuit Television Cameras (CCTVs) are essential to consumer-friendly video management and are commonly used for traffic management. There are a number of CCTVs within Western Wake County. The majority are within the Town of Cary; however, NCDOT and North Carolina Turnpike Authority (NCTA) have also installed CCTVs along the major facilities within the study area (i.e., I-40, I-540, and US 1/64). The Town of Cary uses Genetec software integrated with Econolite's CENTRACS ATMS video management module for video management. NCDOT uses Protronix Video Pro software for management of their CCTVs. **Table 2.3** lists the number of CCTVs used for traffic management within the study area. NCDOT provides snapshots of camera images online at DriveNC.gov (see **Figure 2.13**).

Table 2.3: Traffic Management CCTVs in the Study Area

	Total Number of CCTVs	CCTVs Managed by NCDOT	CCTVs Managed by the Town
Town of Apex	5	5	-
Town of Cary	176	10	166
Town of Fuquay-Varina	-	-	-
Town of Holly Springs	1	-	1
Town of Morrisville	-	-	-
	182	15	167

ADDITIONAL SOFTWARE SYSTEMS

There are several additional software systems used for management of various aspects of the traffic signal system within the Town of Cary. These include the following software systems and applications:

- Video Detection Systems and Related Software:
  - Autoscope Network Browser
  - AutoSupervisor Suite (6 Versions)

- Accessible Pedestrian Signals (APS) and Related Software:
  - EZ APS Tool Box
  - Intelligent Configuration Utility

- CCTV Camera Viewing and Troubleshooting Software:
  - NVIDIA's Frameview
  - Genetec Omnicast Live Viewer 4.8
  - Genetec Omnicast Config Tool
  - Genetec Security Center 5.4
  - Axis Companion
  - Axis Device Manager

- Emergency Vehicle Preemption Software:
  - Opticom On Site

- School Zone Flasher Software:
  - School Zone Calendar Configuration
  - Tapco Configuration Tool

- Traffic Signal Cabinet Monitoring Software:
  - Glance Cabinet Monitoring System

- Malfunction Management Unit Remote Monitoring:
  - EDI ECcom Version 4.0.4

2.3 TRAFFIC MANAGEMENT FACILITIES AND STAFFING

The Town of Cary currently has a Traffic Management Center (TMC) located in Town Hall and a Public Works TOC.

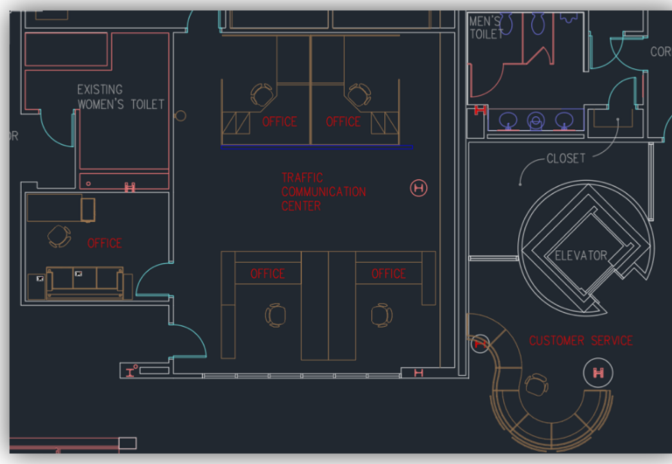


Figure 2.14: Town of Cary TMC Layout

- The TMC is approximately a 20’ x 25’ room that houses four Cary staff members. The traffic supervisor is located in an adjacent room and connected to the TMC space. Staff in the TMC include two positions associated directly with the Cary signal system along with two positions that are not directly related to the signal system.
- Cary signal system staff use Lenovo laptops to connect to the ATMS. Each staff member has three 24” monitors at their workstation. There are a total of three workstations. The TMC contains twelve 44” monitors assembled on one centrally located wall that comprise the video wall and one 55” LCD TV.
- The server room contains all central hardware necessary for operations of the ATMS. This includes the core switch, CCTV video servers, main Uninterruptible Power Supply (UPS), Cisco UCS Storage Server, and a workstation to manage the video wall.
- The TOC is approximately a 12’ x 20’ room that houses one staff member. There is also a 30’ x 30’ room that houses 10 traffic signal technicians, a 10’ x 12’ room housing two sign technicians, and a 50’ x 40’ open bay area used for testing and assembly of traffic signal cabinets.

Figure 2.15: Town of Cary TMC

The Town of Cary staffing and assigned responsibilities are indicated below in **Table 2.4**.

Table 2.4: Town of Cary Traffic Operations Staffing

Staff Position	Position Responsibilities
Traffic Sign and Signal System Technician	• Primary responsibility is to maintain signs with entry level responsibility for signal maintenance. Responsible for installation and maintenance of all Town traffic signs. Maintains inventory of signs and related hardware. • Assists with traffic signal projects, fiber-optics, and special events as needed.
Traffic Signal System Technician 2	• Assists the Senior Traffic Signal System Technician with assigned duties. • Assists with signal and fiber-optic preventive maintenance, new installations and upgrades, and repairs of damaged infrastructure. • Assists Sign Department as needed.
Senior Traffic Signal System Technician	• Manages assigned traffic signal section. Responsible for signal and fiber-optic preventive maintenance. Provides contractor inspection for new installations and upgrades. Responsible for new traffic signal installations and upgrades. Makes repairs to damaged infrastructure. • Assists Sign Department as needed.
Traffic Operations Electronic Technician	• Maintains, repairs, and updates traffic signal equipment. • Coordinates software maintenance with vendors and updates software as necessary. • Responsible for reviewing plans, testing all new contractor equipment, fiber tracking, and ESRI GIS updates. • Implements annual conflict monitor testing and school flasher program.
Traffic Operations Field Supervisor	• Manages day-to-day operations, staff, merit reviews, scheduling, sign and signal related projects, fiber transfers, reviews design plans, preventive maintenance plans, and traffic signal implementation.
Traffic Signal Systems Specialist	• Supports Capital Projects Initiatives o Construction of new signals and PHBs; traffic calming related projects; SPOT improvements; signal system camera expansion; pedestrian/bike improvement projects • Supports Signal/ITS Initiatives o Signal operations & monitoring; incident management; connected vehicle; ATSPM; corridor timing; signal plan reviews; system network operations (ATMS, fiber management, and signal system camera expansion); departmental policy and SOP development • Supports Planning Initiatives o Traffic count program; webpage; GIS; contracts; vision for additional services and programs; organizational development commitments; traffic engineering policy and standard procedure development; standard specification development; pilot projects
Traffic Signal Systems Operations Engineer	• Supports Capital Projects Initiatives o Construction of new signals and PHBs; traffic calming related projects; SPOT improvements; signal system camera expansion; pedestrian/bike improvement projects • Supports Signal/ITS Initiatives o Signal operations & monitoring; incident management; connected vehicle; ATSPM; corridor timing; signal plan reviews; system network operations (ATMS, fiber management, and signal system camera expansion); departmental policy and SOP development

	• Supports Planning Initiatives ○ Traffic count program; webpage; GIS; contracts; vision for additional services and programs; organizational development commitments; traffic engineering policy and standard procedure development; standard specification development; pilot projects

Traffic Engineering Supervisor	• Supports Capital Projects Initiatives
	  ○ Construction of new signals and PHBs; traffic calming related projects; SPOT improvements; signal system camera expansion; pedestrian/bike improvement projects
	• Supports Signal/ITS Initiatives
	  ○ Signal operations & monitoring; incident management; connected vehicle; ATSPM; corridor timing; signal plan reviews; system network operations (ATMS, fiber management, and signal system camera expansion); departmental policy and SOP development
	• Supports Development Review
	  ○ Rezonings & Quasi-judicial cases (Town Council meetings, Planning and Zoning meetings, Zoning Board meetings); Traffic Analysis Report Program and QJ TIA Review; Development plan review; DRC meetings; NCDOT District coordination
	• Safety and Mobility Initiatives
	  ○ NCDOT Division coordination; traffic calming; sight distance issues; 311 citizen issues; driveway requests; pavement marking review and applications; signing reviews and modifications
	• Supports Planning Initiatives
	  ○ Traffic count program; webpage; GIS; contracts; vision for additional services and programs; organizational development commitments; traffic engineering policy and standard procedure development; standard specification development; pilot projects

Operations Coordinator – Signs and Signals	• Manages all aspects of traffic operations, budget, maintenance, traffic signals, signs, fiber-optic, training, trucks, equipment, monies, contracts, employees, projects, etc.
Network IoT Architect	• Responsible for network switch configuration and network security.
IT Operations Manager	• Responsible for network security and firewall management.

The Towns of Apex, Fuquay-Varina, and Morrisville do not currently operate a TMC.

The Town of Holly Springs does not have a TMC, or staff dedicated to traffic signal operations and maintenance. However, the Town’s fiber infrastructure terminates in a server room at the Law Enforcement Center.

The Town of Holly Springs staffing and assigned responsibilities are indicated below in **Table 2.5**.

Figure 2.16: Town of Holly Springs Law Enforcement Center

Table 2.5: Town of Holly Springs Traffic Operations Staffing

Staff Position	Position Responsibilities
Transportation Engineer	• Responsible for engineering and design of transportation network signal locations and signal project management.
Transportation Planner	• Responsible for evaluation of the Transportation Improvement Program (TIP) and growth needs related to traffic and safety.
Chief Information Officer	• Manages the physical fiber infrastructure, including installation, maintenance, relocations, splicing, etc. • Coordinates with the Town of Cary and NCDOT.
IT Operations Manager	• Responsible for management of all logical networks.

NCDOT Division 5 provides operations and maintenance oversight for all NCDOT signals in Western Wake County. Some staff positions for the Division 5 Traffic team that are relevant to this study are provided in **Table 2.6**.

Table 2.6: NCDOT Division 5 Traffic Staffing

Staff Position	Position Responsibilities
Division Traffic Engineer	• Responsible for the maintenance, operation, and installation of signs, pavement markings, and traffic signals. Perform and review traffic engineering studies for speed limits, new traffic signals, intersection improvements, crosswalks, and other various requests. Coordinates with local governments, elected officials, and the general public regarding the implementation of any needed improvements or new infrastructure and knowledge of traffic and transportation engineering practices and principles. Reviews and approves any special event requests. Oversees the administration of purchase order contracts and annual maintenance budgets.
Deputy Division Traffic Engineer	• Coordinates the operations of the Division's Traffic Engineering Signals Group. Leads employees in applying traffic engineering principles in the operation and maintenance of traffic signals. Performs traffic engineering investigations, evaluates coordinated signal timing and recommends adjustments as needed, and makes recommendations and seeks funds for safety and operational improvements.
Assistant Division Traffic Engineer	• Conducts traffic engineering investigations such as speed zone studies, performs intersection surveys for traffic signals, develops plans for signing and/or pavement marking needs, provides traffic analysis using various software programs, prepares cost estimates for traffic signal installation, and prepares pavement marking and sign installation plans. Performs signal warrant analysis studies and travel time studies and communicates with contractors, general public, and other governmental agencies concerning traffic engineering policies.
Traffic Operations/Technician	• Conducts investigations/inspection work for operations and facilities to assure compliance with the Manual on Uniform Traffic Control Devices (MUTCD), NCDOT Standards and Specifications, and contract agreements. Responsible for traffic ordinances and traffic engineering investigations. Conducts field studies to determine traffic volume, speed, effectiveness of signals, adequacy of lighting, and other factors influencing traffic conditions under the direction of a traffic engineer.
Traffic Signal Supervisor	• Supervises technicians involved in the installation, maintenance, and repair of electrical and electronic traffic control systems. Technician duties performed include installing traffic signal equipment by wiring/installing signal head, wiring detectors, and installing/wiring controllers. Supervises activities that trace out electrical wiring diagram, locate trouble, dismantle control, replace worn or faulty parts, and reassemble and test the traffic control system.

The North Carolina Department of Information Technology (NCDIT) provides an Intelligent Transportation Systems (ITS) team for operations and maintenance support of servers and network connectivity across the state. NCDOT's Signal System Timing and Operations team leads the implementation of closed-loop signal systems and signal timing efforts in the state with the high-level goals of balancing and minimizing traffic congestion as well as promoting smooth traffic flow along a corridor. This team has developed a Signal System Timing Philosophy Manual for a consistent and data-driven approach to signal timing assessment and re-timing of NCDOT traffic signals on regular intervals. **Figure 2.17** on the next page, provides a flowchart of the timing process.

Figure 2.17: NCDOT Signal System Timing Philosophy Manual

TRAFFIC MANAGEMENT CENTER CONNECTIVITY

Providing network connectivity between municipal agencies will enable integration of existing and proposed traffic signal systems in the future. Through the expansion of local networks and the need for shared resources, there are some existing agency Center-to-Center (C2C) connections. For security reasons, those specific locations are not listed in this report.

INFORMATION TECHNOLOGY STANDARDS

As fiber-optic cable has become a more prevalent communication media in transportation systems, the technologies available for traffic signal cabinet connectivity to upstream aggregation switches have also advanced exponentially. Many agencies have a fiber-optic network for their agency enterprise and are seeing similarities in the networks being designed for transportation systems. Increasingly, transportation departments are partnering with information technology departments for the design, operations, and maintenance of transportation systems.

The Town of Apex and the Town of Fuquay-Varina work closely with their respective IT departments and noted that the IT departments are responsible for all management of the Town fiber. There are no documented IT standards relative to traffic signal systems.

The Town of Holly Springs IT department manages the Town's fiber plant. In Holly Springs, some of the fiber is used for agency enterprise, some for partner-connectivity, and some for signal connectivity. The IT department has expectations and standards for fiber communication design, construction, and maintenance, which include:

- Currently evaluating ruggedized Ethernet switch option. (The Town will not be installing Cisco switches as they do not integrate with the existing network management system.)
- Only Town of Holly Springs IT staff can maintain switches (will be coordinated with NCDOT).
- The fiber network will be fully maintained, owned, and operated by the Town at all times.

The Town of Cary IT department is a primary stakeholder in the Town's traffic signal system. The existing management of the fiber-optic network requires the following IT standards be met.

- Ethernet switches are Cisco IE 3300 (see **Figure 2.18**).
- All switches are currently programmed through the Town IT department. For private construction, switches are purchased by the private entity and provided to the IT department for programming. For public projects, switches are purchased by IT and programmed by IT prior to installation in the cabinet.
- Standard cabling connections are used for fiber.
- The Town IT department manages software licenses and maintenance fees.

Figure 2.18: Cisco IE-3300 Traffic Signal Cabinet Switch

2.4 USER ACCESS

As traffic signal systems become more integrated across multiple agencies, it is important to evaluate and consider what users will need access to the system and for what purposes. The integration of technologies must maintain access for critical staff to infrastructure elements while also maintaining a secure network environment. This section seeks to document current user access requirements for each municipality.

USER ACCESS REQUIREMENTS

The user access requirements and responsibilities vary from town to town. There may be users with periphery access who check in on the system intermittently, and there are users that rely on daily access and the ability to continually adjust the system. The staff who require access to the traffic signal system and its related elements, by category, are listed below in **Table 2.7**.

Table 2.7: User Access Needs by Category

Staff Category	Apex	Cary	Fuquay-Varina	Holly Springs	Morrisville
Director of Infrastructure/Operations	-	1	-	2	-
Operations Manager/Supervisor	1	1	-	1	-
Transportation Engineering	1	1	-	1	-
GIS and Field Specialist/Technicians	-	12	-	4	-
IT and Network Operations	1	2	1	2	-

2.5 EXISTING OPERATIONS AND MAINTENANCE

SUMMARY OF OPERATIONS AND MAINTENANCE AGREEMENTS

Signal and ITS infrastructure installed by NCDOT are designed to NCDOT standards. Where agencies do not have the capability, NCDOT provides operations and maintenance for these signals. When agencies have the capability, NCDOT will enter into Schedule C & D Agreements for reimbursement of O&M costs for signals at intersections on state-owned roadways.

The Schedule C Agreement requires the municipality to maintain a Level of Service "C" or "good" for traffic signal operations to be eligible for reimbursement. Components of a "good" Level of Service include:

Table 2.8 Schedule C Agreement Components

Maximum Emergency Response Times	• Trouble calls – 4 hours • Repair knockdowns – 8 hours • Absence of a signal indication – next working day • Repair/replace inoperative loops – 15 calendar days
Operational Performance Reviews	• Perform required minimum tasks at 6-month, 12-month, and 2-year intervals • (minimum tasks are detailed within the Schedule C agreement) • Replace LED modules after 5 years of service

System Component Repairs	• Repair equipment in a timely manner to support emergency and operational needs • Upgrade equipment firmware as appropriate to address items affecting operational efficiency and safety • Certify the proper operation of conflict monitors/malfunction management units on an annual basis

The Schedule D Agreement requires the evaluation and preparation of timing plans and the ongoing operations of the signal system. Again, a Level of Service "C" or "good" is required to be eligible reimbursement.

The minimum requirements to achieve Level of Service "C" or "good" within Schedule D are:

- At least 80% of signalized intersections are monitored and actively controlled by the system.
- Timing plans and day plans are evaluated on intervals of no greater than 18 months. Corridors with annual traffic growth >5.0% require new timing plans to be identified annually. On average, required new plans are developed and implemented within six months of identification.
- The municipality obtains the data that is used to evaluate system operations and performance.
- Timing plans for newly installed intersections are implemented within 30 calendar days of the installation of the traffic signal.
- The municipality has an active, ongoing operational performance program for operation of the traffic signal system in which system communication components and central site hardware are tested and evaluated on intervals of no less than two times per year.
- A minimum of 80% of all system detectors are operational at any given time. The maximum time to repair failed detection devices is 60 calendar days.
- The control center is staffed by qualified personnel during the AM and PM peak hours. The operations staff is on-call during other times of expected high traffic volume.
- The municipality uses traffic responsive timing plans where appropriate. Threshold values are evaluated annually.

Given the size of the Cary signal system and the staffing resources, the Town of Cary has existing agreements in place to operate and maintain signals in both Morrisville and Holly Springs. These agreements require the same minimum operational levels of service as the Schedule C&D Agreements.

- The Towns of Cary and Morrisville have an agreement in place for Cary to maintain and operate several signals within the Morrisville town limits. There are several Morrisville signals on, or very close to, the Town of Cary fiber-optic network. The agreement between these two towns outlines that Morrisville will design and install infrastructure needed in the Morrisville town limits. Upon completion, inspection, and acceptance of the infrastructure, the Town of Cary will own, operate, and maintain the assets.
- The Towns of Cary and Holly Springs also have an agreement in place for Cary to maintain and operate the signal at Ballentine Street and Main Street in downtown Holly Springs. The Town of Holly Springs changed out the equipment at this location to meet the Cary specifications, installed a CCTV for Cary to monitor the intersection and provided a direct fiber connection between the signal and the Town of Cary TMC. This is the first signal under this type of agreement between Cary and Holly Springs.

Chapter 03

DETAILED IMPLEMENTATION PLAN

Throughout Western Wake County, there are several miles of existing fiber infrastructure owned by varying agencies. While the fiber infrastructure was installed to meet individual agency needs at the time, the area is seeing increasing growth and development, and as such, the need for additional fiber connectivity is growing. As agencies continue to expand their footprint, the boundaries between jurisdictions begin to blur, providing opportunity for connectivity between agencies.

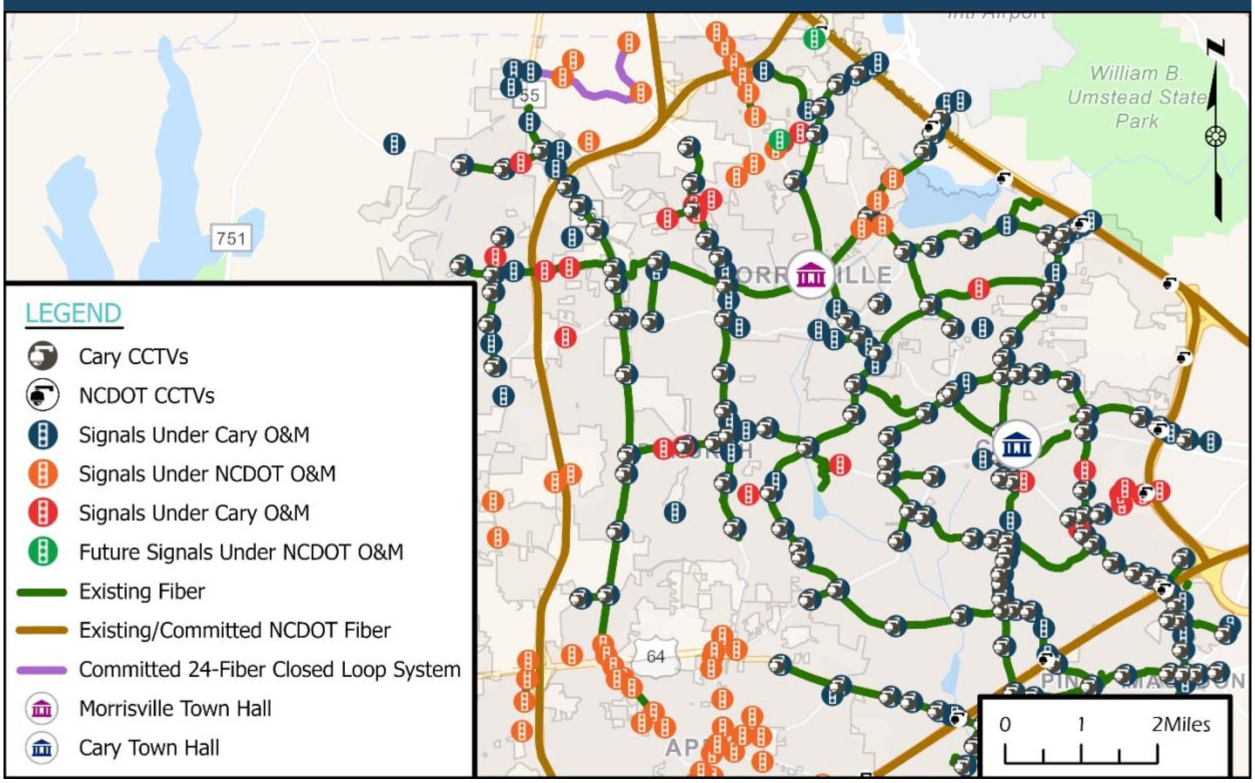
3.1 COMMUNICATION NETWORK INTEGRATION, SECURITY, & RELIABILITY

CARY/MORRISVILLE NETWORK INTEGRATION RECOMMENDATIONS

The fiber infrastructure throughout the Town of Cary provides connectivity to Cary's traffic signals. Additionally, because of the non-linear jurisdictional boundary between Cary and Morrisville, there are several signals within Morrisville that are connected to the Cary signal system. Given this extensive crossover between boundaries, Morrisville and Cary have a standing agreement in which the Town of Cary operates and maintains several of Morrisville's signals. This agreement functions in the best interest of the agencies and the public. Both agencies have expressed a desire to continue working under this arrangement.

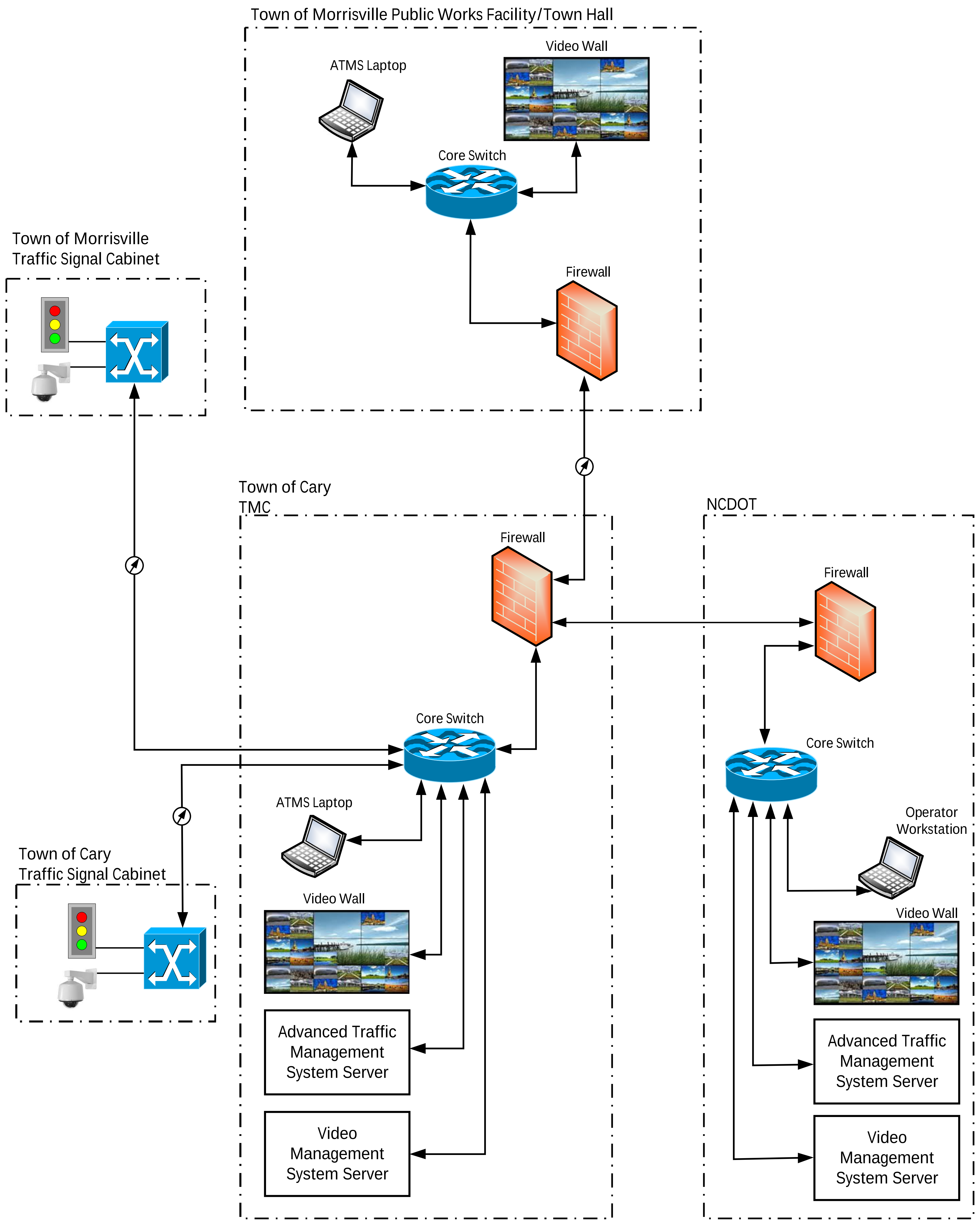
The map in **Figure 3.1** shows the proximity of the two agencies' infrastructure and the existing connectivity. Cary has existing fiber along Davis Drive, Aviation Parkway, and Airport Boulevard that connects with Morrisville signals. Project U-5967 (Let Mar. 2026), which proposes fiber in the Kitt Creek Road area, is currently under design and is shown in purple in the figure below as a committed project. At the time of this writing, it has not been determined if the U-5967 project will tie into the Cary system or remain an NCDOT closed-loop system.

Figure 3.1: Existing Infrastructure and Connectivity



Currently, all Morrisville and Cary signals with fiber-optic connectivity are connected on that fiber directly from the field cabinet to the Town of Cary server room in Town Hall. This communication architecture is recommended for future signal connectivity as well. In addition, a fiber-optic center-to-center connection is recommended between Cary and Morrisville to provide Morrisville staff with viewing capabilities of signal operations and camera images. A dedicated fiber path between the Morrisville and Cary servers will provide that connection. This center-to-center connection will likely require additional infrastructure on the exterior of the building near Morrisville Town Hall. The remaining connection can likely utilize existing fiber-optic infrastructure. The details related to this center-to-center connection need to be further verified through detailed design. Each agency should provide their own firewall on their respective end of this connection. **Figure 3.2** on the following page, shows how the traffic signal cabinets will be directly connected to the Town of Cary servers and the server-to-server connection between agencies is a separate connection.

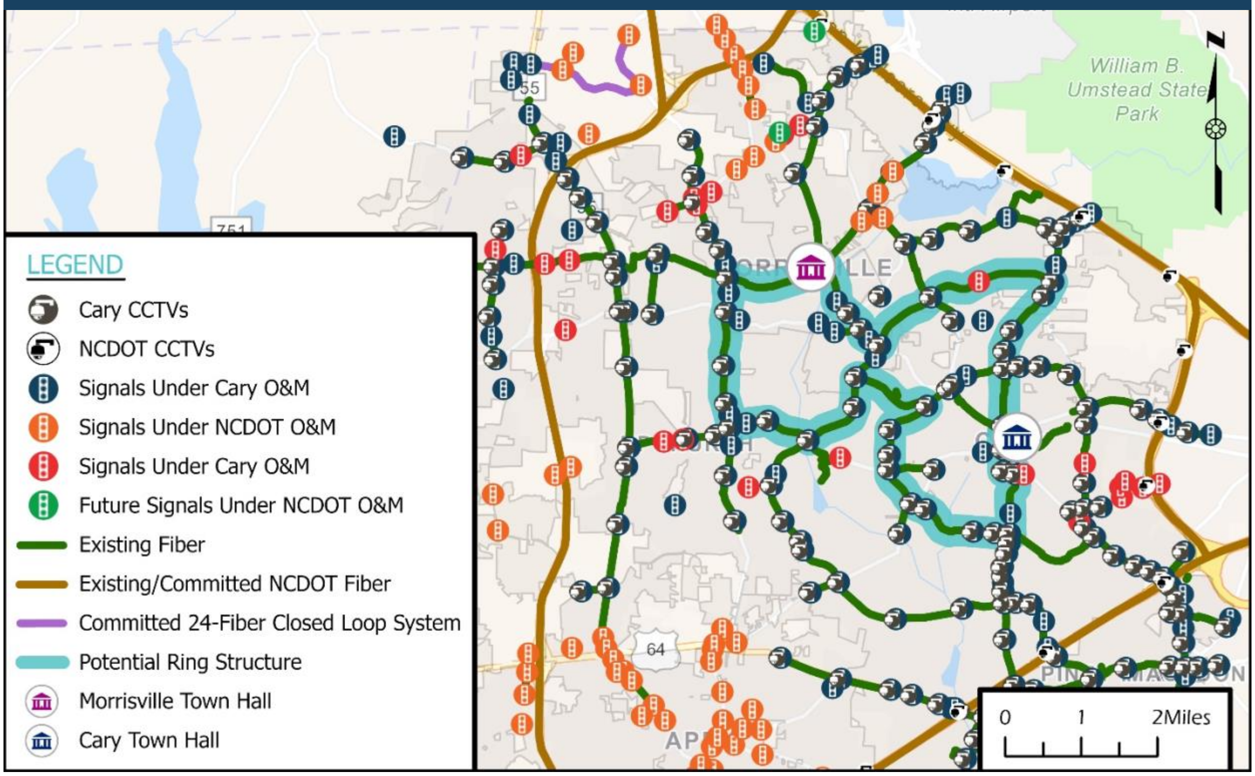
Figure 3.2: Towns of Cary and Morrisville Architecture



A dedicated fiber path between the two agencies would provide the center-to-center (C2C) connectivity described but would be more reliable if there were another path-diverse redundant connection. A path-diverse connection is also recommended for each of the Town of Morrisville traffic signal communication groups to the Town of Cary TOC. This could be achieved with two continuous fiber paths through the signal system network. **Figure 3.3** identifies potential path-diverse C2C connections with the teal buffer. It should be noted that identifying a fiber path for the C2C connectivity could be an involved undertaking if there are corridors with little to no fiber available. A detailed review of fiber usage will identify the most viable route option. If limited to no fiber is available, there are other options that could be explored in the near-term. For example:

- Consider another route through the network that has more available spare fiber.
- Consider bidirectional wavelength-division multiplexing (WDM) transmission. Bidirectional WDM uses a single fiber for data transmission in both directions by use of different wavelengths of laser light, allowing for expansion of the network without adding more fiber.
- Consider reconfiguring the network to have an aggregation point in Morrisville. The network would then route signal data/control to the nearest server, which could free up fiber in other segments of the network.

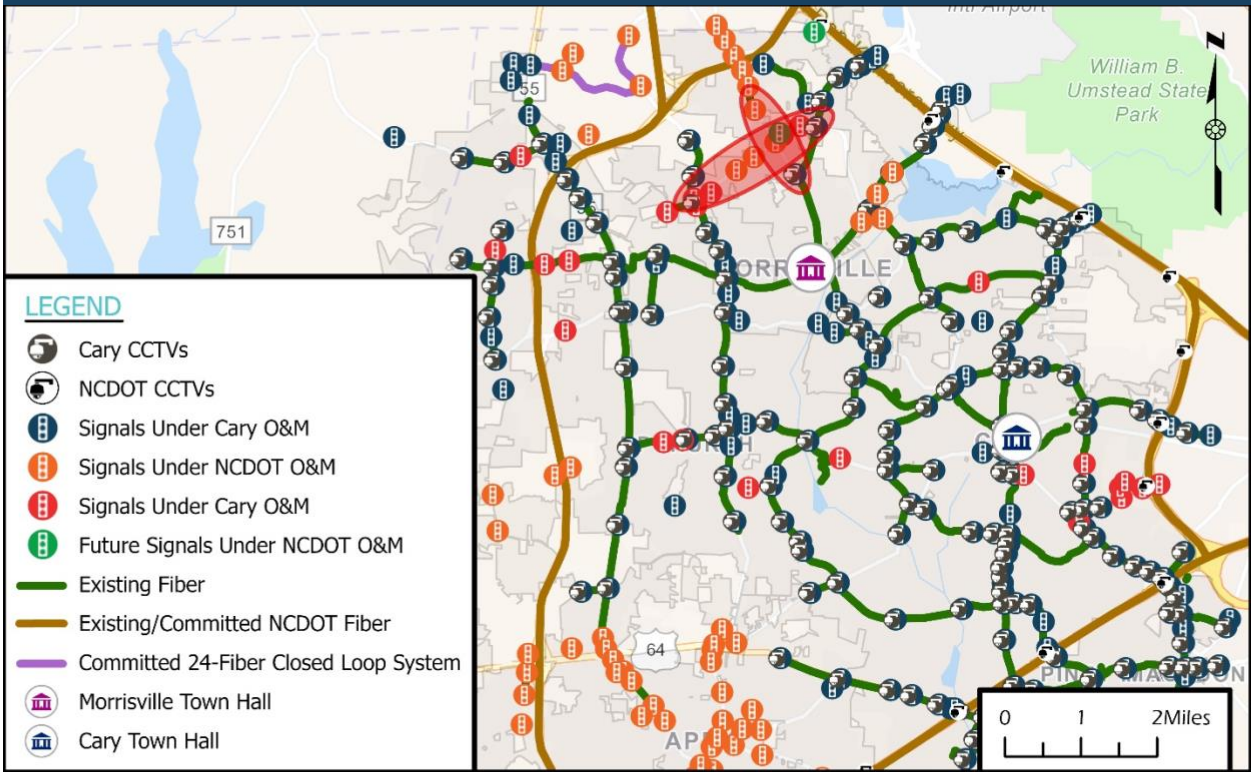
Figure 3.3: Existing Gaps in Connectivity



STRATEGIES FOR INCREASED CONNECTIVITY

There are a couple of strategic corridors in Morrisville where there is currently no fiber-optic connectivity, but if it was added, a majority of the Cary and Morrisville systems would be integrated. These corridors are NC 54 and McCrimmon Parkway; these gaps in connectivity are highlighted with red bubbles in **Figure 3.4**. There are two TIP projects in design that will install fiber along McCrimmon Parkway (U-5747A, Let Oct. 2022) and NC 54 (U-5750, Let Nov. 2022) covering parts of these two corridors. It is recommended that any remaining gaps in communication infrastructure be constructed.

Figure 3.4: Existing Gaps in Connectivity



As each Town continues to develop, new signal installations should be evaluated for how they will be managed from an operations standpoint. Installing a fiber link from the new signal to the existing fiber route should be included where it is not cost prohibitive. In cases where the new signal is too far from existing fiber and is not along a trunk route, the new signal could include wireless or cell modem communication technologies to ensure remote operations management capabilities. A Fiber Master Plan would enable the Towns to accurately address some fiber-optic network extensions and their connectivity to traffic signals through development requirements, grant funding, and future CIP/TIP projects. A regional or local ITS Master Plan should be conducted.

While this study is focused on the Western Wake region, it will be important to consider network connectivity to neighboring agencies outside of the Western Wake region for enhanced traffic operations and management throughout the Triangle. These connections will also enable advanced traffic management strategies in cooperation with NCDOT such as integrated corridor management along these corridors. A regional ITS Master Plan would dig into these details; however, the proximity between Cary and Durham signal system infrastructure is such that achieving connectivity between the two would be relatively simple and cost-effective.

Traffic signal system networks result in far-reaching and intertwined municipal networks due to the location of traffic signals throughout a municipality. The return-on-investment (ROI) for fiber-optic connectivity of traffic signals alone is very high when considering travel time, safety, and emissions. The ROI can be even higher when the traffic signal system fiber-optic network is leveraged for additional uses. Within the transportation spectrum, connectivity for smart transit systems, smart parking systems, and bicycle/pedestrian corridors is often available along many municipal corridors. Similarly, smart city connectivity can be used to enhance integration and reduce paid internet service connections throughout a municipality. It is recommended that both Cary and Morrisville consider these connections for advanced technologies when planning and investing in their fiber-optic network.

The fiber connectivity proposed in **Figure 3.4** above will provide for the majority of the Morrisville signals to be connected to Town of Cary fiber. However, there are a few outlying signals not on these major corridors. While the initial solution for these locations may be wireless or cellular communications, having a plan for future fiber connectivity will benefit the Town of Cary as new development occurs. The specific location of each signal should be evaluated on a case-by-case basis as to the feasibility of adding a fiber project for connectivity. In certain instances, it may be possible to develop an agreement with NCDOT/NCTA for connectivity to disparate signals through existing fiber-optic infrastructure along controlled access facilities.

RELIABILITY, AVAILABILITY, AND NETWORK SECURITY REQUIREMENTS

Operations rely on the availability and security of the network. To maintain real-time operations, it is imperative that the network maintain connectivity. The proposed redundant fiber connectivity along diverse paths (described earlier in this section) will provide for a reliable network that can withstand power outages at individual cabinets or higher network availability during a scenario where fiber is damaged by nearby construction or environmental conditions. This assurance of availability coupled with a securely maintained network will maximize the network potential. The reliability of a traffic signal system network is often gauged by the availability of the network and devices.

Traffic signal controllers operate independently based on local controller configurations and do not require system connectivity. However, for coordination with adjacent signals, enhanced operations, enhanced maintenance, and implementation of advanced technologies, communication connectivity is required. Signal system management relies on the network to enable real-time monitoring and response to traffic-related events.

FIBER CONNECTIVITY

As later discussed in Chapter 4, extension of the existing ring topology for Morrisville signals would enhance redundancy and connectivity. The addition of a distribution switch at Morrisville Town Hall may also reduce fiber demands along trunk routes back to the Cary data center.

If fiber is constructed in a redundant configuration along NC 54 and McCrimmon Parkway arterials as mentioned in the previous section, then the majority of signals and cameras in Morrisville would have fault-tolerant redundancy from the data center. Coupled with a strong operations and maintenance plan, this will drastically reduce signal downtime and result in improved traffic operations in the region. Additional discussion of O&M approaches for enhanced device availability is discussed in Chapter 5.

The criticality of fiber connectivity to signals and devices should be considered for each signal and device, because over-building for 99.9999% uptime for every traffic signal and device may be cost prohibitive for the region, especially in the interim. The best approach is to evaluate the specific operational needs and develop standard categories for availability and reliability. For example, NCDOT has developed a new performance-based ITS maintenance program that separates devices into three categories (general, essential, and vital) and establishes availability requirements for devices in those categories based on their operational needs. Under this program, the traffic signals along the NC 54 corridor that parallels I-40 may be considered vital, whereas the traffic signal at McCrimmon Parkway and Perimeter Park Drive may be essential or general.

NETWORK MANAGEMENT AND SECURITY

The Town of Cary is already using enhanced network design and management strategies for increased resiliency. There are several network management protocols for enhanced features that may be evaluated; examples include Resilient Ethernet Protocol (REP), which enables a local area network to effectively have a primary and backup communication link within a fiber ring. This enables a series of traffic signals to have separate paths (primary and backup) to the traffic management center without causing confusion (network storms) within the network. Similarly, Hot Standby Router Protocol (HSRP) enables field network switches to maintain connection with a primary and backup router at the traffic management center to allow the network to maintain uptime during an individual router failure. These features result in enhanced availability and uptime for the network.

The Town of Cary should continue management of an expansion of network monitoring software to facilitate proactive and responsive network maintenance to support a performance-based approach to network maintenance.

There are some simple steps to increase network security, such as implementation of port security on individual network switch ports. While this does create some considerations for Operations and Maintenance, it also reduces the potential for intrusion in the field. Many new software applications also utilize web-based platforms that by nature introduce external connections to the transportation network. Reducing security threats related to these applications can be accomplished in one of two ways: by restricting web-based access or by developing specific security audit standards with which web-based software vendors must comply.

Each agency's IT department will be instrumental in providing network management support. There should be collaboration between agencies to ensure network security. It is understood that each agency within the region likely undergoes cybersecurity assessments on a regular basis. In this case, it is recommended that the agencies work together to self-perform a transportation network-specific cybersecurity assessment that considers security standards and threats for the transportation industry. USDOT has completed substantial research in this area; several resources are provided below:

- CISA's report on transportation systems: Transportation Systems Sector-Specific Plan - 2015 (cisa.gov)
- TMC cybersecurity guidelines: USDOT ITS Research - Additional References and Guides
- Cybersecurity incident response: USDOT ITS Research - Additional References and Guides
- ITS penetration testing: USDOT ITS Research - Informative References Tailored for the ITS Environment
- Connected Vehicle Security: USDOT ITS Proof of Concept – Security Credential Management System (SCMS)

FIELD CABINET SECURITY

Electronic cabinet security can range from door alarms that notify operators in the TMC to the installation of electronic keys that are programmed to give certain staff access to certain cabinets. Enhancing the security of the network results in improved resiliency and limits the risk to the transportation network.

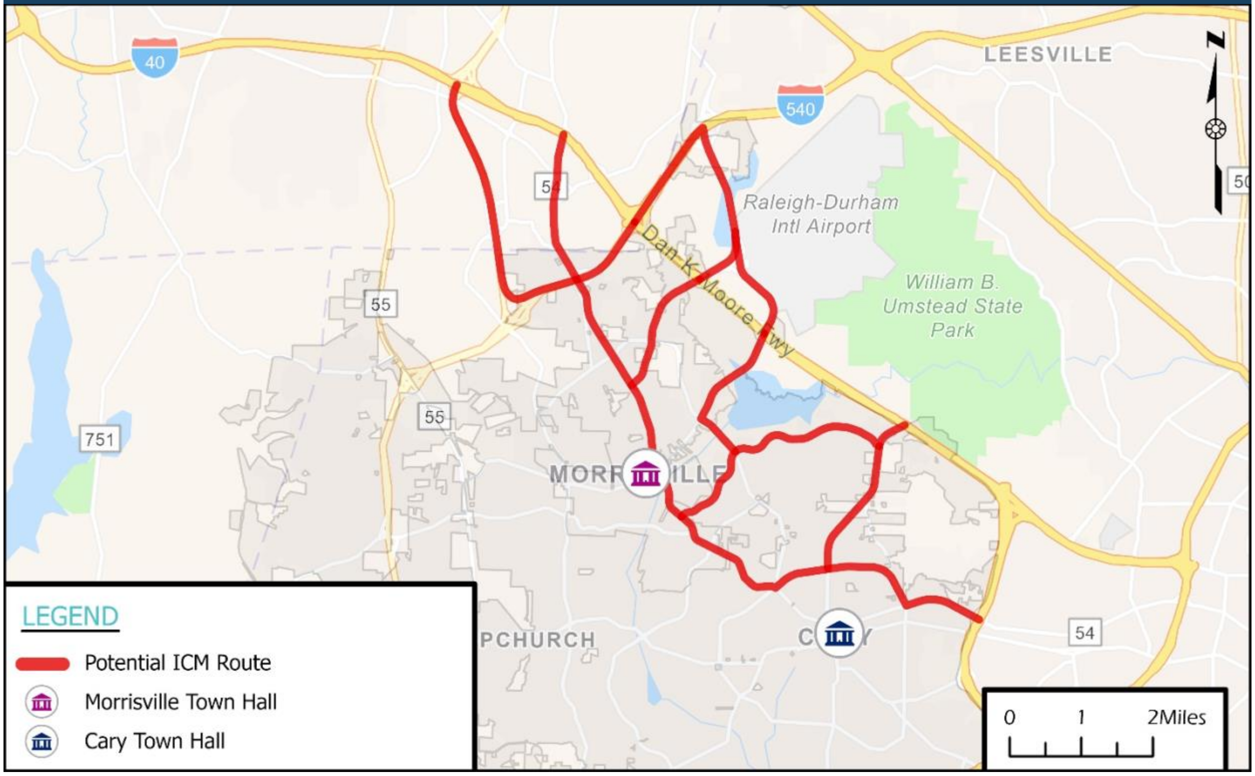
CONNECTION TO STATEWIDE NETWORK FOR ICM & MANAGED MOTORWAYS INTEGRATION BENEFITS

NCDOT maintains an extensive fiber network across the state, with several miles of fiber throughout Wake County. This fiber infrastructure is primarily along interstates and major highways; however, there are other state routes that have NCDOT fiber. As referenced in **Figure 3.2**, there is an existing connection between the Town of Cary and the NCDOT State Traffic Operations Center (STOC).

NCDOT has recently implemented several integrated corridor management (ICM) projects that provide for pre-designed and pre-programmed alternate routing options. When travel conditions along an interstate deteriorate to a level of needing to provide alternate routing information, the STOC operators can provide motorists with alternate route messaging, and the signal timing along those alternate routes can be adjusted to accommodate the temporary change in traffic patterns. While there has not been an ICM project within the vicinity of this study, there is the potential to use the parallel NC 54 route (shown in Figure 3.5) as an alternate if there were a need to divert motorists off I-40. The associated corridors that would be used for ICM routing include NC 54, Aviation Parkway, Airport Blvd, I-540, NC 147, and Harrison Ave. Fiber connectivity between the signals along these corridors will help ensure a uniform update of signal timing plans as they are adjusted to the needs of the ICM implementation.

There are future plans for the implementation of Managed Motorways along I-40 in this same section. These plans would include ramp metering which would have impacts on the local arterial signal system. Therefore it is recommended that the regional signal system be integrated with any future ramp metering or managed motorways system.

Figure 3.5: Potential ICM Route



As noted, integrated corridor management along I-40 will be an important consideration along these arterial corridors; therefore, additional network connections at key locations for dynamic trailblazers, connected vehicle roadside units, and potentially arterial DMS should be considered when designing trunk fiber along I-40's parallel arterials and cross-connecting arterials with I-40 interchanges.

TRAFFIC SIGNAL SYSTEM NETWORK IMPLEMENTATION

As traffic signal systems have increasingly utilized Ethernet communications, there has been a growing collaboration between transportation divisions and information technology (IT) divisions. The Town of Cary IT department is an integral stakeholder in the traffic signal system operations. It will be imperative for the Town of Cary and the Town of Morrisville to define the roles of each IT group in the management of the traffic signal system. The expectations of responsibilities will need to be set for both the field components as well as the data center components.

It is expected that all signal system components will use Ethernet communication technology. The Town of Cary standard field Ethernet switch is the Cisco IE 3300. They also have a Cisco core switch in the server room. The network switch vendor will not impact the ability to share data between agencies. However, the ability to manage the network security may be more complicated with varying switch equipment. While there are several Ethernet switch manufacturers, the environmental conditions necessitate a ruggedized, field-hardened switch for use in traffic signal cabinet installations.

Another component of the Ethernet switch is the small form-factor pluggable transceiver (SFP). Cisco recommends the use of Cisco SFPs for their Ethernet switches. Other manufacturers make SFPs that fit Cisco switches; however, some functionalities of a homogenous Cisco network may be compromised with use of varying SFP manufacturers. Due to the variation in costs of both the switches and their components, the expectation of switch manufacturers should be determined upfront.

The Town of Cary has a highly capable and experienced IT department that manages the switch hardware for the Town's traffic signal system network. In addition, Town of Morrisville signals that are currently maintained by the Town of Cary are integrated as part of the Town of Cary traffic signal system network. Due to these features, when additional Town of Morrisville traffic signals are transitioned to Town of Cary operations and maintenance, they should be integrated as part of the Town of Cary traffic signal system network and be subject to Town of Cary network hardware specifications and requirements.

The Town of Morrisville and the Town of Cary should develop a redundant, path-diverse center-to-center connection between the Town of Cary Traffic Management Center and the Town of Morrisville Town Hall and future Public Works facility. A redundant center-to-center connection between the Towns would enable performance management analysis and monitoring by the Town of Morrisville as discussed in Chapter 5 (Operations and Maintenance). The network connection should be secured on each end by each Town's respective IT department with a firewall for security purposes.

3.2 USER ACCESS FROM NETWORKED AND REMOTE LOCATIONS

Current signal operations and maintenance in the Town of Morrisville are performed by NCDOT and the Town of Cary with no involvement from Morrisville or staff dedicated to these efforts. Given this agreement, current access to cabinets, software, and data is limited to both NCDOT and Cary for the signals operated and maintained by each of these entities.

As discussed, Morrisville and Cary intend to develop a formal agreement for Cary to continue to operate and maintain the Morrisville signals. These agencies may also wish for Cary to assume management of the NCDOT signals within Morrisville to help with more seamless management of the system. These coordinated efforts provide Cary the means to view, operate, and access all the signals within these towns. The Town of Morrisville has indicated a desire to have access to view and recommend adjustments to their network of signals for special events. As discussed in Chapter 2, there is currently no user access in Morrisville to any of the traffic signals.

Even though the signal system is not managed by Morrisville, it is recommended that the Town of Morrisville designate user access to several of their staff to enable them to measure performance of the system and support special event management. Having this ability in-house would also position the Town for more hands-on involvement in the future if they desired. At a minimum, it is recommended that at least one member of the Public Works team have access.

For Cary, additional staff will be required to provide operations support to an increased number of signals and maintain their current operational standards.

DEVELOPMENT OF STANDARD ROLES AND RESPONSIBILITIES FOR USER ACCESS

User access roles and responsibilities will be important to define the capabilities of varying staff. Morrisville staff should be able to view the performance measure of their own local signals as well as monitor and use pan/ tilt/zoom (PTZ) for their future cameras as they are implemented. However, during active operations, if the Town of Cary operator is analyzing the operations at a particular signal, their PTZ control should supersede another user's access. Defining roles and responsibilities between varying members of each agency would clarify use of the system. While some roles and responsibilities can be managed with user tiers in software, sometimes a simple, written policy is all that is needed to achieve efficient operations.

Based on peer reviews and Core Team meetings held with the Western Wake agencies, it was also identified that Fire Departments, Police, and Emergency Departments should be provided access to CCTV cameras. Therefore, it is recommended that these capabilities be established with local emergency agencies as well as roles, responsibilities, and potential software user tiers for their access and potential control of cameras.

SHARED BUILDING SPACE

Due to the physical distance between several of the Morrisville signals and the signal operations office in Cary where maintenance and signals staff are located, responding to signal needs on the periphery can be time intensive. Cary and Morrisville have already worked through a solution for Morrisville to provide traffic signal maintenance/storage space in their new Public Works facility, which is currently under design. This will provide for storage space and a meeting space with contractors, when necessary. It is also recommended that the Towns consider connectivity to allow for using this space as a signals lab as the need arises.

A local memorandum of understanding (MOU) will be required for both parties to agree on level of operations, maintenance, and reimbursement. An MOU Roadmap will be provided in the Appendix.

3.3 SOFTWARE INTEGRATION, LICENSES, AND CONTRACT REQUIREMENTS

Understanding the goal for Cary to manage all signals in Morrisville, it is important to consider that signals being transitioned from NCDOT operations/maintenance to Cary operations/maintenance would require an upgrade within the local traffic signal cabinet to transition from Oasis firmware to ASC/3 firmware on the controller.

NCDOT is in the process of selecting and procuring a new local and central signal system software in addition to a separate process of selecting and procuring new local and central signal system software. Meanwhile, Cary has also expressed interest in upgrading their current management system sometime after NCDOT selects their vendor. It is recommended that if both NCDOT and Cary plan to upgrade their systems, creating a regional/statewide standard would make for an easier integration and operation of all signals. This integration could involve having a regional software that all parties have access to or could be a mix of software packages that have capabilities to share information between systems. Based on peer reviews, it was noted that agencies across the country have been able to integrate different software and systems into a regional effort, but while having a mix of software is expected in the near-term, the long-term recommendation for the region is to have a unified central signal system software platform to integrate all signals. Given that the combined system would be hosted by Cary, having the same software would require less future training for maintenance and operations. Considering each of these guiding principles, listed below are some of the possible options for the regional integration.

1. **NCDOT selects Centracs/EOS and Cary continues with Centracs/ASC/3 and converts to Centracs/EOS in the long-term.**

   This option would be limited to NCDOT selecting Centracs for their new central signal software but could align with the current Cary software. This option would also allow Cary to upgrade their current system with the same signal system software company, which would limit some of the additional training required for operations and maintenance.

2. **NCDOT selects a different central signal software vendor and Cary decides to replace their current system in the long-term.**

   This option would also allow both systems to standardize in the long-term. However, the new central signal system would require additional training and resources for all staff and integration of the current equipment. This option could provide access to more features for asset management and newer technologies, depending on the vendor selected.

3. **Both NCDOT and Cary perpetually have different systems.**

   This would require a regional host to operate both systems and be trained to operate and maintain both. This could also complicate the integration and having a future regional TMC that can process both systems at the same time.

Overall, these options are dependent on NCDOT's direction for the software they will be purchasing, which has not been finalized at the time of the preparation of this document. It will be most beneficial for the regional system to plan for either option 1 or 2 to standardize all systems.

Agencies with similar systems were interviewed as part of this project, and the recommendation from each of these entities is that no matter which option is selected, this effort will require regional training to operate the new system. Agreements will need to be implemented with the selected vendor(s) to establish a new software that can be used across the region by all parties. It is recommended that these agreements integrate decisions based on data sharing, user roles, access to all software and maintenance, and performance agreements. Based on recommendations in peer reviews, strong agreements in writing allow all entities to be on the same page regarding responsibilities and expectations.

CONTROLLER UPGRADES

It is recommended that traffic signals be upgraded to 2070LX controllers with ASC/3-2070 firmware on a phased approach with the upcoming Morrisville closed-loop project and concurrent roadway projects that will be upgrading signals. This new firmware will enable the Town of Cary to manage these traffic signals in a similar manner as the rest of the system.

CCTV INSTALLATIONS

In terms of ancillary software systems, Morrisville currently does not have CCTV cameras or other modules attached to their system. Therefore, for any future CCTV integrations, it is recommended that Cary and NCDOT continue to have agreements for sharing video in the area. The Town of Morrisville has expressed the desire to add cameras to some of their traffic signal corridors. These cameras would need to be integrated with the regional system and added to individual intersections based on operational needs. Two possible corridors to consider for CCTV camera implementation include NC-54 and McCrimmon Parkway. Additional camera installations on these corridors would likely provide a high ROI with the added traffic operations situational awareness.

3.4 SIGNAL SYSTEM HARDWARE INTEGRATION COMPONENTS

As mentioned in previous sections, currently all Town of Cary and some Town of Morrisville cabinets are NEMA TS 2. NCDOT-maintained signal cabinets within Morrisville are 332/336S. Maintenance activities are more complicated with different hardware as it requires different training and additional parts inventory.

Within the Western Wake region, there are roughly an equal number of signals in the Town of Cary as there are in the Towns of Apex, Fuquay-Varina, Holly Springs, and Morrisville combined. So from a Western Wake County regional standpoint, roughly the same cost is involved with transition to either platform. However, from a Triangle regional standpoint, all other municipalities that border Western Wake (Raleigh, Durham, Garner, etc.) are standardized on the 332/336S cabinets. NCDOT does not recommend transitioning any additional systems to the NEMA TS 2 cabinet standard as that is moving away from the statewide cabinet standard. Additionally, NCDOT has recently added the Advanced Traffic Controller (ATC) cabinet to the Qualified Products List (QPL). While the features of these ATC cabinets may be the direction of the industry in the future, the Department does not have a definitive plan to migrate toward all ATC cabinets in the near-term.

Given these parameters, there are four different options to be evaluated:

1. **Operate a regional mixture of 332/336S and NEMA TS 2 Cabinets.**

   This option is the most likely solution for the near-term until an agreement on standardization and the implementation of a TIP project can be implemented. It is expected that in this scenario, the regional system host will require additional training and effort to be able to maintain and operate both types of cabinets. Given the amount of effort and additional staff needed, this solution will likely reduce the current efficiency for maintenance but will save time and costs for implementing a TIP project that would replace Town of Cary cabinets.

2. **Convert the Town of Cary signal cabinets to 332/336S.**

   This option would involve investigating the long-term effort to standardize all cabinets in the region and have the same cabinet as surrounding municipalities to Western Wake County. Given the number of current signals in Cary with NEMA TS 2 cabinets, it is expected that this project would require a large TIP project to be implemented.

3. **Convert the Town of Morrisville to NEMA TS 2 Cabinets.**

   Like Option #2, this solution would require a project in the long-term to replace all existing cabinets for regional standardization. NCDOT does not recommend moving more of the region in this direction.

4. **Replace all cabinets with the Advanced Traffic Controller (ATC) cabinets.**

   This option would be the most expensive and would require the most effort for training since no current system is utilizing ATC cabinets. However, this option would provide new cabinets and equipment to all municipalities in the long-term. This option would advance the region toward newer technology in the industry, use low voltages, and allow an open architecture to integrate with different advanced transportation technologies. However, given the higher cost of these cabinets, this would likely require a series of TIP projects to phase the transition.

Overall, no matter what option is selected, additional training for the regional system host will be required in the near-term to maintain and operate the current equipment. While the Morrisville signals managed by Cary have been converted to NEMA TS 2 cabinets, there are still about 14 signals in Morrisville that have not been integrated into the Cary system yet. Additional training for the 332/336S cabinets will allow Cary to maintain and operate the remaining cabinets. During one of the small group meetings with NCDOT, NCDOT offered to assist with additional training and resources for Cary’s staff to operate and maintain 332/336S cabinets in the near-term.

Chapter 04

HIGH-LEVEL IMPLEMENTATION PLAN

4.1 COMMUNICATIONS NETWORK INTEGRATION, SECURITY, AND RELIABILITY

HIGH-LEVEL NETWORK ARCHITECTURE OPTIONS

Signal system connectivity via fiber-optic cable provides for the most reliable communication means for traffic signals and devices. As the Towns of Apex, Holly Springs, and Fuquay-Varina build out fiber connectivity to their traffic signals, the data center that will aggregate the data and house the necessary servers needs to be identified. Holly Springs has indicated their fiber-optic network terminates in their server room at the Law Enforcement Center. Apex and Fuquay-Varina have not specified how a traffic signal system fiber network would look in their jurisdictions.

Typically, a signal system fiber-optic network requires increasing the size of fiber-optic cables as the fiber nears the data center. A municipal fiber-optic network functions much like a tree, where individual signal communication groups are like the leaves and require 1 to 4 fibers for communication with the TMC. The spurs and connections on the periphery of the network require 12 to 24 fiber cables. As the fiber from these communication groups aggregate along a redundant homerun path with other connections from the periphery of the network (much like a tree's limbs), the fiber-optic cables become larger. As multiple fiber optic cables near the data center, they aggregate again into the largest cable sizes, often a 48, 72, 144, or larger fiber cable. There are several network topologies that can be applied to municipal networks, and the approach for selecting a network topology often depends upon the following factors:

- **Ability to initially plan, design, and construct large fiber cables.** If proper planning is performed to evaluate the long-term fiber needs and municipalities are capable of building 100% to 200% spare into their fiber networks, this provides ample infrastructure for future expansion.
- **IT preferences for network topology.** Most information technology departments prefer a fully mesh network (**Figure 4.2**), where each access layer switch has two connections to a central core or distribution switch. Due to the nature of extensive geographic networks, ring or star topologies are often used for signal system networks to reduce fiber consumption and provide a balance between infrastructure cost and redundancy/reliability of the fiber networks. There are important implications and considerations for each topology that will need to be considered by the agency that is maintaining the fiber-optic network. **Table 4.1** provides a high-level review of various network topologies in use for traffic signal system networks. Any of the topologies proposed in **Table 4.1** are good solutions for a regional traffic signal system network, and determination of the exact topology for any specific system should be heavily influenced by operations and maintenance considerations for the managing IT department.
- **Ability to have aggregation or distribution network hardware within the network.** As demonstrated in the tree metaphor above, traffic signal system networks tend to aggregate fibers into larger cable sizes the closer the infrastructure is to the TMC. One way to reduce fiber-optic cable size requirements or to enable additional spare cable is to terminate the fiber-optic cable at an intermediate location and aggregate the network using a distribution network switch. For example, say 10 traffic signal communication groups are terminated at a distribution switch location. Each of the 10 communication groups carry network traffic for 10 traffic signals. Each communication group has 2 fibers with Gigabit bandwidth. Those 20 fibers could be terminated and connected to a distribution switch, which would aggregate the Gigabit bandwidth for 10 network links to 10Gigabit bandwidth over two redundant network links that are connected to the TMC. This aggregation approach will thus reduce the fiber cable needs from 20 fibers required to 4 fibers required for the remaining distance to the traffic management center.
- **The use of bi-directional optical transceivers within the network.** Although moderately more costly, bi-directional optical transceivers reduce fiber utilization by only using 1 fiber for both transmitting and receiving data to a traffic signal access switch. Bi-directional optical transceivers now have the capability to cover large distances of 10km to 80km and are capable of Gigabit, 10Gigabit, and higher bandwidth. Use of

these optics can drastically reduce the size of planned fiber-optic infrastructure or make the most of new fiber-optic infrastructure.

- **The use of passive optical networks.** Passive optical networks are used extensively for fiber to the home applications and can be used in municipal traffic signal system networks as well. These networks offer drastic reductions to fiber-optic cabling infrastructure requirements but also come with some trade-offs with respect to redundancy as each end point is typically connected to only 1 fiber from 1 direction.

Table 4.1: High-Level Review of Various Network Topologies for Traffic Signal System Networks

Topology	Description	Pros	Cons
Ring Topology	Field switches (at each field device: traffic signal, camera, etc.) are grouped into communication groups of 10-15 switches that share the same 1- or 2-fiber local area network in a multi-drop configuration. The field switches on each end of the communication group have an uplink to a core switch.	• Reduces the fiber cabling infrastructure required over star or mesh network topologies. • Path-diverse redundancy for every device along the ring path. Diverse-path redundancy for most of the network link for devices that spur off the ring path.	• Moderate troubleshooting complexity. • Communication group size is limited to 10-15 signals to reduce video latency.
Ring Topology with Distribution Switches	This topology is like the ring topology above in that field switches (at each field device: traffic signal, camera, etc.) are grouped into communication groups of 10-15 switches that share the same 1- or 2-fiber local area network in a multi-drop configuration. The primary difference for this topology is the field switches on each end of the communication group have an uplink to a distribution switch location (either in a building or a special field cabinet) that aggregates multiple communication group networks onto a higher capacity network connection to the core switch.	• Reduces the fiber cabling infrastructure required even further between aggregation points and the TMC. • Path-diverse redundancy for every device along the ring path. Path-diverse redundancy for most of the network link for devices that spur off the ring path.	• Increased troubleshooting complexity. • Communication group size is limited to 10-15 signals to reduce video latency. • Requires additional facilities and hardware for distribution network locations.
Mesh Topology	Field switches (at each field device: traffic signal, camera, etc.) have a direct 1- or 2-fiber local area network connection to a core switch.	• Path-diverse redundancy. • Simpler troubleshooting and management. • Eliminates latency concerns altogether.	• Requires an extensive fiber-optic cabling infrastructure to accommodate current conditions and future growth.
Mesh Topology with Distribution Switches	Field switches (at each field device: traffic signal, camera, etc.) have a direct 1- or 2-fiber local area network connection to a distribution switch location (either in a building or a special field cabinet) that aggregates multiple communication group networks onto a higher capacity network connection to the core switch.	• Reduces the fiber cabling infrastructure required between distribution switches and the core switch location. • Path-diverse redundancy. • Simpler troubleshooting and management. • Eliminates latency concerns altogether.	• Requires an extensive fiber-optic cabling infrastructure to accommodate current conditions and future growth, but distribution switches can be used to reduce fiber consumption as needed in key locations.

Each of the topologies mentioned are applicable for regional traffic signal system networks. Municipalities should evaluate and use one of the four topologies described in **Table 4.1**. However, each network can be customized based on local needs and managing IT preferences.

Signal System Field to Central Communications

Within each signal system in a regional traffic signal system network, traffic signals are connected via fiber-optic cable from the field cabinet to the TMC. Since there is not an established signal system in Apex, Holly Springs, or Fuquay-Varina, this section seeks to provide recommendations on how those systems or other agencies may be connected in the future.

The network architecture options described in the previous section provide many alternatives for how signals can most efficiently be connected to a TMC. There are four primary considerations for evaluating the most effective approach for any regional system:

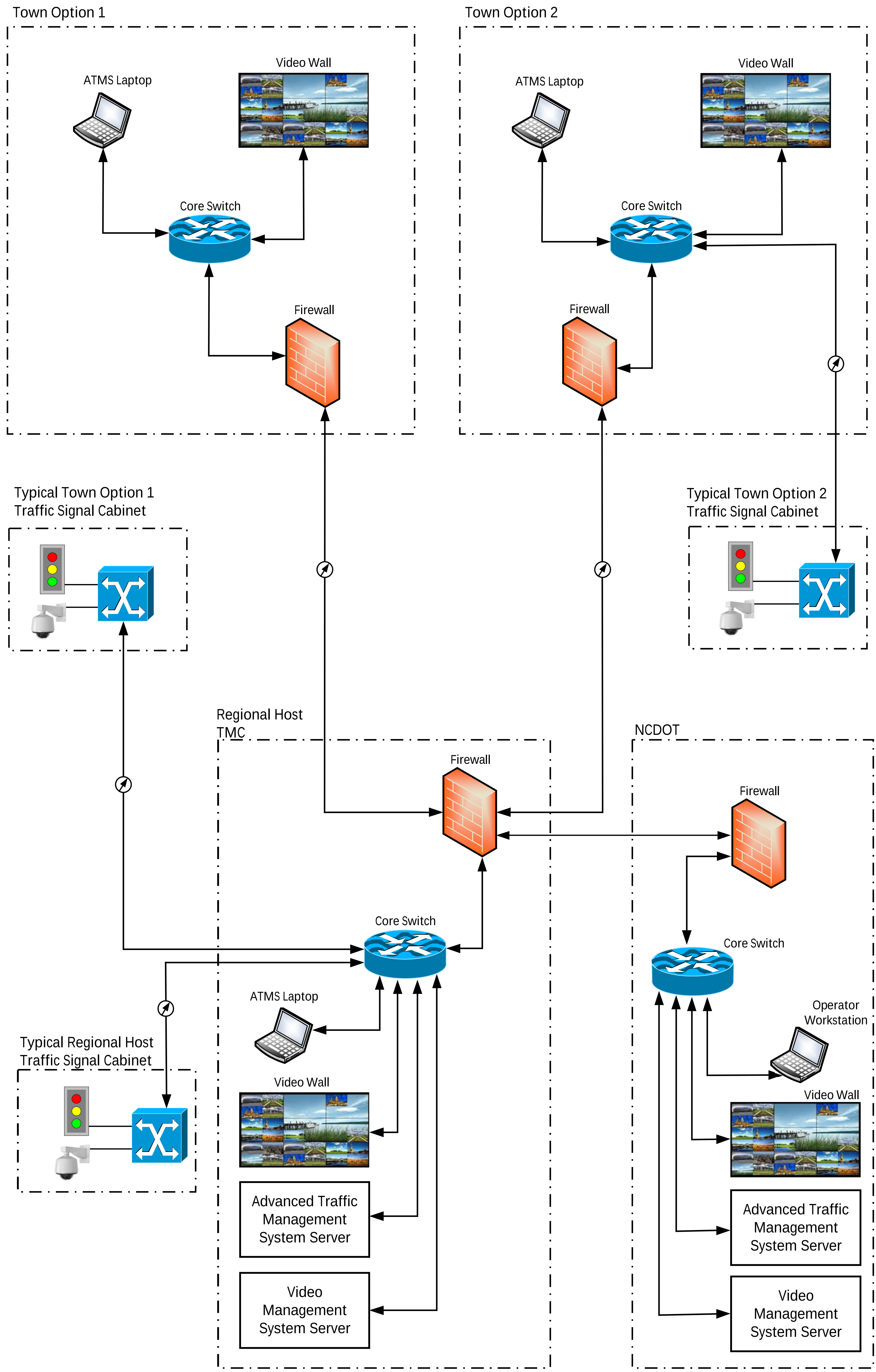
- Existing Infrastructure: What infrastructure has already been deployed and how can we most effectively steward those existing assets?
- Construction Feasibility/ROI: What can we feasibly fund from a construction perspective that will provide the highest level of ROI?
- Reliability, Availability, and Security: How can we design the network with the highest levels of reliability, availability, and security given the other constraints?
- Operations and Maintenance Considerations: What can we most effectively manage? What are our staff trained to manage?

Figure 4.1 portrays two options for signal connectivity within the Western Wake region, but in both cases, there is only one Regional Host TMC. This TMC would house the system servers. The two options primarily differ in how the traffic signals are interconnected with the traffic management system.

- Option #1 shows a traffic signal cabinet with a fiber connection to the Regional Host TMC. The signal and CCTV data would be connected to the TMC, and the municipality would access the data through the secure, firewalled, center-to-center connection. The Town fiber network is laid out to send traffic signal data to the Regional Host TMC. This would require a field network topology that is centered upon the Regional Host TMC. Any number of the architecture options listed in Section 4.1 may be used to reduce the fiber consumption requirements for this larger network.
- Option #2 shows a traffic signal cabinet with a fiber connection to the municipality's own data center where the core switch passes it through the firewall to the Regional Host TMC server via a center-to-center connection. The Town would still access the data through the secure, firewalled, fiber ring connection. The Town fiber network is laid out to bring traffic signal data to the Town's data center to be passed through to the Regional Host TMC. This would require a field network topology that is centered upon the Town's data center rather than the TMC.

Figure 4.1 portrays the field-to-center (F2C) connectivity of signals to the data center as well as center-to-center (C2C) connectivity between agencies. This figure also shows the C2C connection to the NCDOT statewide Centracs server.

Figure 4.1: Two Options for Signal Connectivity within Western Wake Region



Center-to-Center Connections Between Municipalities

The previous section assumes that C2C connections are available between a Regional Host TMC and each participating municipality to enable access to and performance monitoring of traffic signal system software. The Network Architecture Options discussed in Section 4.1 also apply to these C2C network connections.

It is recommended to provide a mesh topology that connects each of the agency data centers along diverse paths that follow a similar fiber-optic ring. This configuration will provide redundancy throughout the network with a diverse routing path. If there were a fiber cut or similar issue between two Town data centers, the mesh topology would allow for sending data around the fiber ring in the opposite direction. A ring configuration will require adequate fiber cabling along the full path of the ring. **Figure 4.2** identifies a potential ring path for center-to-center (C2C) connectivity and the directions of communication data to allow for redundant interconnection between the Town of Apex, Town of Cary, Town of Fuquay-Varina, Town of Holly Springs, and Town of Morrisville. **Figure 4.3** provides an example of how each of the municipalities could have a redundant C2C connection with the Town of Cary, but the same ring structure is flexible to enable any combination of one to many or many to many C2C connections between the municipalities.

Center-to-Center Connection to NCDOT

NCDOT maintains a statewide traffic signal system server that enables interconnection with many of the signals that NCDOT operates and maintains across the state. This server also can have C2C connections with municipal traffic signal systems to enable signal timing coordination in some of the following scenarios:

- Signal timing coordination along the periphery of municipal signals where NCDOT operated/maintained signals are part of the same corridor as municipal operated/maintained signals. This scenario would enable more seamless signal operations along jointly managed corridors.
- Initiation of integrated corridor management (ICM) signal timing plans when ICM is initiated by the Statewide Traffic Operations Center (STOC) to manage incidents.

In addition, NCDOT has a 24/7/365 Statewide Traffic Operations Center that is constantly monitoring congestion, primarily along freeways in the Triangle region. The ability for NCDOT staff to view municipal camera feeds along freeway routes or for municipalities to view NCDOT camera feeds along arterial routes would be mutually beneficial among agencies.

It is recommended to provide a mesh topology that connects the Regional Municipal TMC to NCDOT’s data center (either the STOC or other) along diverse communication paths. This configuration will enable software integration for signal timing coordination and ICM along the corridors within the region.

Figure 4.2 Western Wake Fiber Diagram

Western Wake Fiber Network Diagram

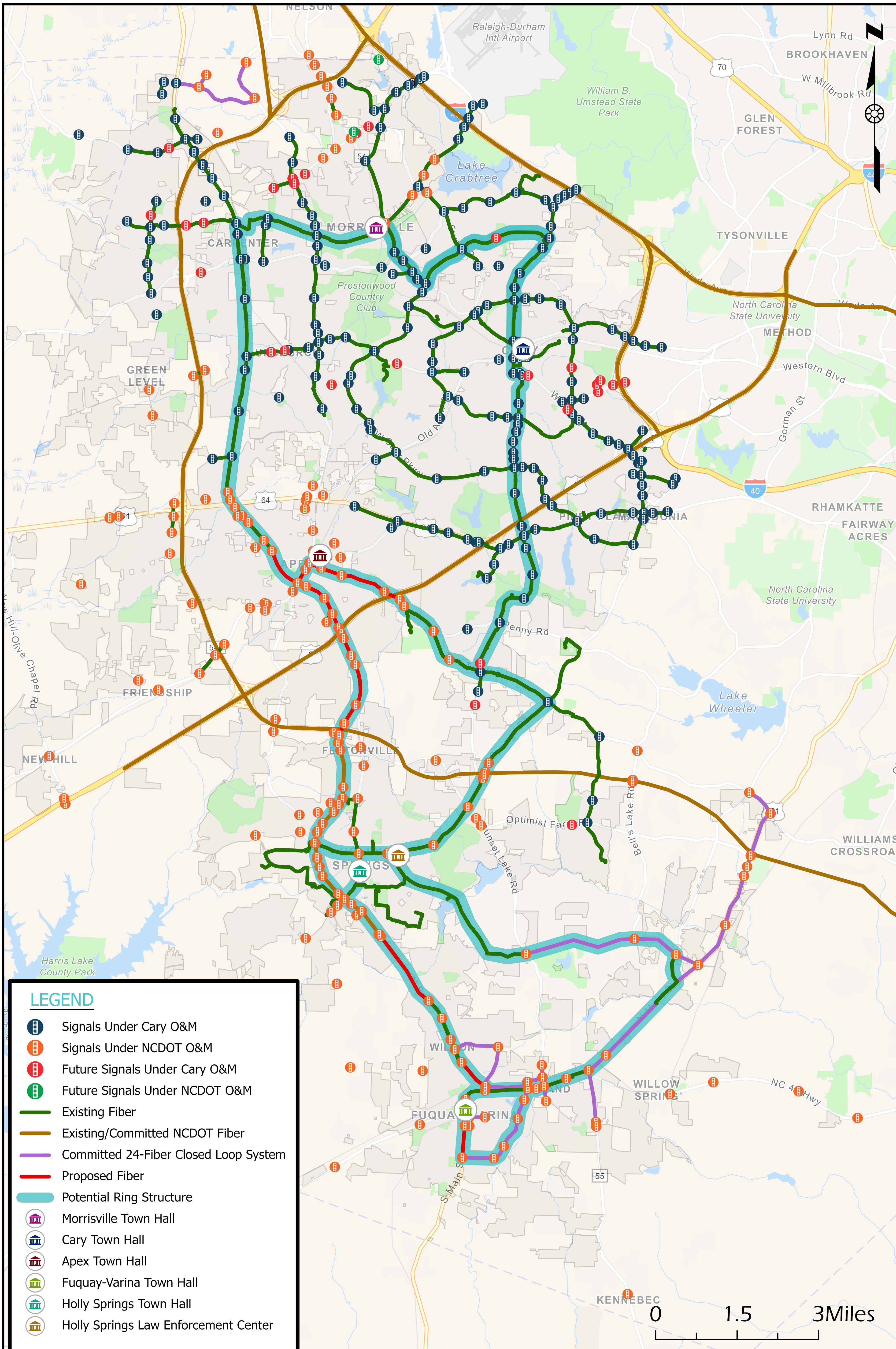
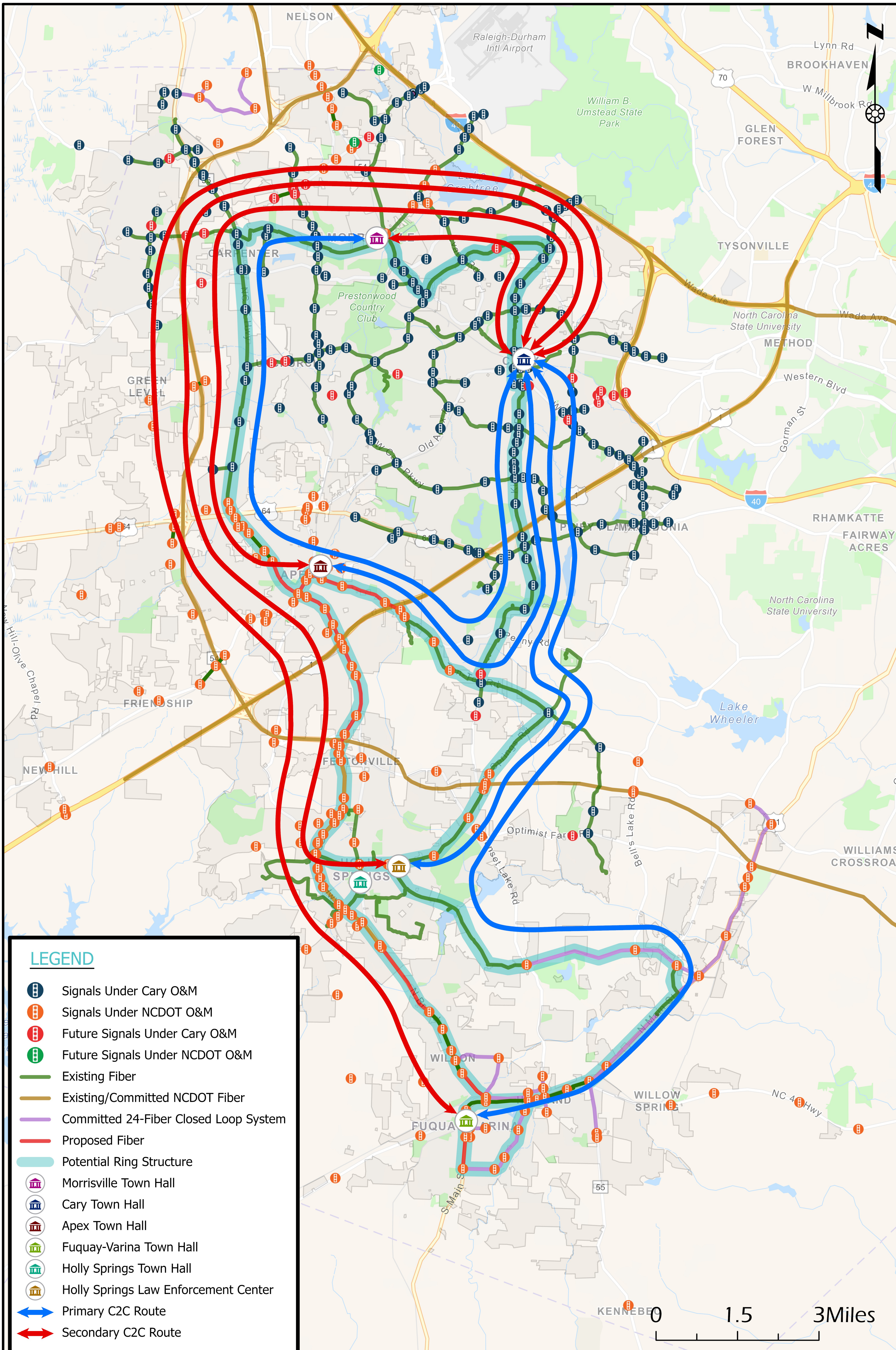


Figure 4.3 Western Wake Fiber Network Center-to-Center (C2C) Diagram

Western Wake Fiber Network Center-to-Center (C2C) Diagram



REGIONAL INTERCONNECTIVITY AND RESILIENCY

The Towns of Apex, Holly Springs, and Fuquay-Varina each have some existing fiber communication infrastructure, and in many cases, it belongs to NCDOT. There are also varying planned projects that will provide for additional fiber-optic communications.

- The Town of Apex has several closed-loop systems that provide communication to many of their signals as shown in Chapter 2, **Figure 2.6.**
- The Town of Holly Springs has installed fiber to most of their signals as shown in Chapter 2, **Figure 2.9**.
- The Town of Fuquay-Varina has a funded NCDOT TIP project that will install fiber to approximately 40 signals.

To further integrate the signal systems in the Western Wake County, it will be important to address the gaps in the existing communications infrastructure along the proposed communication ring. **Figure 4.2**, above, identifies these gaps with the red line on the map. It is recommended to construct fiber-optic cable connections along the proposed regional communication ring to provide redundant, regional connectivity among municipalities**.**

It would be best to perform a regional communications infrastructure study to identify fiber-optic cabling needs for both field-to-central and center-to-center connectivity throughout the region. Multiple future TIP projects are on the horizon for the region as well as development projects and information technology projects. A study that evaluates the exact fiber consumption needs of each individual municipality as well as the overarching regional fiber consumption needs would provide a roadmap to ensure that each of these disparate projects are working in unity to meet the region's connectivity goals. In addition, this study would take into consideration the various options within a ring, ring with distribution switches, mesh, and mesh with distribution topologies to determine the exact topology proposed for interconnection of the regional system in correlation with local IT departments.

An evaluation of gaps in traffic signal system communications along the periphery of the system should be conducted. There may also be instances where a signal is isolated and not communicating with a signal system server. These locations need to be evaluated on a case-by-case basis to determine the feasibility of establishing connectivity, either via fiber, cell modem, or wireless communications. While the initial solution for these locations may be wireless or cell modem communications, having a plan for future fiber connectivity will benefit the Town as new developments come. As the towns develop further, new signal installations should be evaluated for how they will be managed from an operations standpoint. Installing a fiber link from the new signal to the existing fiber route should be included where it is not cost prohibitive. In cases where the new signal is too far from existing fiber the new signal should include wireless or cell modem communications technologies to ensure remote operations management capabilities.

While this study is focused on the Western Wake region, it will be important to consider network connectivity to neighboring agencies outside of the Western Wake region for enhanced traffic operations and management throughout the Triangle. These connections will also enable advanced traffic management strategies in cooperation with NCDOT such as integrated corridor management along these corridors. A regional ITS Master Plan would dig into these details, however, the proximity to the City of Raleigh and Town of Garner signal system infrastructure is such that achieving connectivity would be a cost-effective means of expanding regional connectivity.

Traffic signal system networks result in far-reaching and intertwined municipal networks due to the location of traffic signals throughout a municipality. The ROI for fiber-optic connectivity of traffic signals alone is very high when considering travel time, safety, and emissions. The ROI can be even higher when the traffic signal system fiber-optic network is leveraged for additional uses. Within the transportation spectrum, connectivity for smart transit systems, smart parking systems, and bicycle/pedestrian corridors is often available along many municipal corridors. Similarly, smart city connectivity can be used to enhance integration and reduce paid internet service connections throughout a municipality. It is recommended that network connections for advanced technologies be considered when planning and investing in the fiber optic network.

IT STANDARDS AND RESPONSIBILITIES FOR A REGIONAL NETWORK

As traffic signal systems have increasingly utilized Ethernet communications, there has been a growing collaboration between municipal transportation departments and information technology (IT) departments. It will be imperative for the collaboration to define the roles of each IT group in the management of the traffic signal system. The expectations of responsibilities will need to be set for both the field components as well as the data center components.

It is not necessary to require municipalities within a region to standardize on the same switch hardware. However, standardization of switch hardware is important within a local area network from a management standpoint. Therefore, it is important that traffic signal system communications directly managed by the Regional Host are homogeneous.

NETWORK SECURITY

Each agency's IT department will be instrumental in providing network management support. There should be collaboration between agencies to ensure network security. It is understood that each agency within the region likely undergoes cyber security assessments on a regular basis. In this case, it is recommended that the agencies work together to perform a transportation network-specific cyber security assessment that considers security standards and threats for the transportation industry. USDOT has completed substantial research in this area; several resources are provided below:

- CISA's report on transportation systems: Transportation Systems Sector-Specific Plan - 2015 (cisa.gov)
- TMC cybersecurity guidelines: USDOT ITS Research - Additional References and Guides
- Cybersecurity incident response: USDOT ITS Research - Additional References and Guides
- ITS penetration testing: USDOT ITS Research - Informative References Tailored for the ITS Environment
- Connected Vehicle Security: USDOT ITS Proof of Concept – Security Credential Management System (SCMS)

NETWORK MANAGEMENT

Enhanced network design and management strategies for should be utilized for increased resilience. Examples include Resilient Ethernet Protocol (REP) which enables a local area network to effectively have a primary and backup communication link within a fiber ring. This enables a series of traffic signals to have separate paths (primary and backup) to the traffic management center, without causing confusion (network storms) within the network. Similarly Hot Standby Router Protocol (HSRP) enables field network switches to maintain connection with a primary and backup router at the traffic management center to allow the network to maintain uptime during an individual router failure. These features result in enhanced availability and uptime for the network.

The regional collaborative should employ management of a network monitoring software to facilitate proactive and responsive network maintenance to support a performance-based approach to network maintenance.

There are some simple steps to increase network security, such as implementation of port security on individual network switch ports. While this does create some considerations for Operations and Maintenance, it also reduces the potential for intrusion in the field. Many new software applications also utilize web-based platforms that by nature introduce external connections to the transportation network. Reducing security threats related to these applications can be accomplished in one of two ways, by restricting web-based access or by developing specific security audit standards with which web-based software vendors must comply.

Each agency's IT department will be instrumental in providing network management support.

RELIABILITY, AVAILABILITY, AND NETWORK SECURITY REQUIREMENTS

Operations relies on the availability and security of the network. To maintain real-time operations, it is imperative that the network maintain connectivity. The proposed redundant fiber connectivity (described in Section 4.1) will provide for a reliable network that can withstand power outages at individual cabinets or a fiber cut. This assurance of availability coupled with a securely maintained network will maximize the network potential. The reliability of a traffic signal system network is often gauged by the availability of the network and devices. The traffic signal network availability may differ from a traditional IT network availability, but both rely on consistent reliability of the network.

The criticality of fiber connectivity to signals and devices should be considered for each signal and device. The main reason-being that over-building for 99.9999% uptime for every traffic signal and device may be cost prohibitive for the region, especially in the interim. The best approach is to evaluate the specific operational needs and to develop standard categories for availability and reliability. For example, NCDOT has developed a new performance based ITS maintenance program that separates devices into three categories (general, essential, and vital) and establishes availability requirements for devices in those categories based on their operational needs. For example, the traffic signals along the NC 55 corridor may be considered vital whereas the traffic signal at Old Holly Spring Apex Road and New Hill Road may be essential or general.

FIELD CABINET SECURITY

Electronic cabinet security can range from door alarms that notify operators in the TMC to the installation of electronic keys that are programmed to give certain staff access to certain cabinets. Enhancing the security of the network results in improved resiliency and limits risk to the transportation network.

4.2 USER ACCESS FROM NETWORKED & REMOTE LOCATIONS

With individually managed municipal networks, user access is less intensive to manage, but with the potential integration of a regional system, user access among the municipalities becomes an important consideration. It is recommended that the Regional Host have access to each agency's network to view, operate, and maintain the signals. As mentioned in Section 4.1, having a regional network with fiber backbone will provide all agencies with user access to the regional system. While the Regional Host will have access to view/operate/maintain the system, each agency expressed interest in having access to view and monitor the system. Agencies also indicated that each of their IT departments and their emergency response teams would benefit from access to the system. It is recommended to develop agreements and MOUs on data sharing and software integration between systems and agencies such that the Regional Host can have access to all traffic signals and related ITS devices to maintain the regional system. The MOU Roadmap in the appendix will provide sample language and a template to consider as these agreements are being developed. Additionally, user access should be accommodated for all agencies within the regional network such that each can view and monitor system performance.

For emergency response teams, it is recommended that they can view traffic operations and performance measures such as signal runtime as well as operate camera views within their regional boundaries. The proposed user access for each town's signal system and cameras is shown on the following page in **Tables 4.2 and 4.3**, respectively.

Table 4.2: Traffic Signal User Access Within Defined Agreed Boundaries

Staff Position	Individual Municipality	Regional Host
Director of Infrastructure/Operations	View/Monitor Performance	View/Monitor Performance/ Manage
Operations Manager/Supervisor	View/Monitor Performance	View/Monitor Performance/ Manage
Transportation Engineering	View/Monitor Performance	View/Monitor Performance/ Manage
GIS and Field Specialist/Technicians	View Only	View Only
IT and Network Operations	Network Access by Maintaining Agency Only	Network Access by Maintaining Agency Only
Emergency Response Agencies (fire, law enforcement, NCDOT)	View Only	View Only

Table 4.3: Camera User Access Within Defined Agreed Boundaries

Staff Position	Individual Municipality	Regional Host
Director of Infrastructure/Operations	View all Cameras/Secondary Operation of Local Cameras	Primary Operation/Manage all Cameras
Operations Manager/Supervisor	View all Cameras/Secondary Operation of Local Cameras	Primary Operation/Manage all Cameras
Transportation Engineering	View all Cameras/Secondary Operation of Local Cameras	Primary Operation/Manage all Cameras
GIS and Field Specialist/Technicians	View all Cameras/Secondary Operation of Local Cameras	Primary Operation/Manage all Cameras
IT and Network Operations	Network Access by Maintaining Agency Only	Network Access by Maintaining Agency Only
Emergency Response Agencies (fire, law enforcement, NCDOT)	View all Cameras/Secondary Operation of Local Cameras	View all Cameras/Primary Operation of Local Cameras

Along with access to the signal system and cameras, each local agency should have capability to monitor the performance of the system. This involves reporting, performance criteria, and current signal timing plans implemented for each signal as well as having the capacity to reach out to the Regional Host and measure performance on response times and maintenance based on the agreements implemented.

A local memorandum of understanding (MOU) will be required for all parties to agree on level of operations and maintenance, as well as cost sharing responsibilities.

4.3 SIGNAL SYSTEM SOFTWARE INTEGRATION, LICENSES, AND CONTRACT REQUIREMENTS

Like the integration between Morrisville and Cary, a regional system and standardization of software and hardware is recommended for the Towns of Apex, Holly Springs, and Fuquay-Varina for compatibility with Cary and a regional system. Overall, standardization of systems provides cost benefits in the long term and allows the region to concentrate resources in only one type of system.

NCDOT is also currently in the process of procuring a new Local and Central Signal System Software that could result in further changes in the intermediate term for their signal management system. Meanwhile, Cary has also expressed interest in upgrading their current management system sometime after NCDOT selects their vendor. It is recommended that the Western Wake municipalities in this chapter participate in creating a regional/statewide standard to enable more efficient and effective integration and operation of all signals. This integration could involve having a regional software that all parties have access to or could be a mix of software packages that have capabilities to share information between systems by having systems integrated to share functionalities and data between them.

Based on peer reviews, it was noted that agencies across the country have been able to integrate different software and systems into a regional effort, but while having a mix of software is expected in the near-term, the long-term recommendation for the region is to have a unified central signal system software platform to integrate all signals. Considering each of these guiding principles listed below are some of the possible options for the regional integration.

1. **NCDOT selects Centracs/EOS. Cary continues with Centracs/ASC/3 in the short term and converts to Centracs/EOS in the long-term. If a Regional Host other than Cary was elected for the region, then the Regional Host would also select the Centracs/EOS platform for all the signals in the region.**

   This option would be limited to NCDOT selecting Centracs for their new Traffic Signal System Software but could align with the current Cary and potential Regional Host central software. This option would also allow Cary to upgrade their current system with the same Traffic Signal System Software company, which would limit some of the additional training required for operations and maintenance.

2. **NCDOT selects a different Traffic Signal System Software vendor and Cary decides to replace their current system to be consistent with NCDOT's selection in the long-term. If a Regional Host other than Cary was selected for the region, then the Regional Host would also select the same software vendor as NCDOT.**

   This option would also allow both systems to standardize in the long-term. However, the new Traffic Signal System Software would require additional training and resources for all staff and integration of the current equipment.

3. **Both NCDOT and the Western Wake region perpetually have different systems.**

   This scenario would likely result in an ineffective integration between NCDOT and the Western Wake Traffic Signal System and require higher costs to share data and resources.

Overall, these options are dependent on NCDOT's direction on what software they will be purchasing, but it is recommended for the regional system to go with either Option #1 or #2 to standardize all systems for the Towns of Apex, Fuquay-Varina, and Holly Springs.

Agencies with similar system software were interviewed as part of this project and the recommendation from each of these entities is that no matter which traffic signal system software option is selected, this effort will require regional training to operate the new system. Agreements will need to be implemented with the selected vendor(s) to establish a new software that can be used across the region by all parties. It is recommended that these agreements integrate decisions based on data sharing, user roles, access to all software and maintenance, and performance agreements. Based on recommendations in peer reviews, strong agreements in writing allow all entities to be on the same page regarding responsibilities and expectations.

CCTV INSTALLATIONS

The Towns of Apex, Fuquay-Varina, and Holly Springs have expressed the desire to add cameras to some of their traffic signal corridors. These cameras would need to be integrated with the regional system and added to individual intersections based on operational needs.

REGIONAL PROCUREMENT PROGRAMS

Implementation of regional agreements along with the adoption of regional standardization by all parties will support the development of a regional procurement program. This would enable hardware and software to be refreshed in a standardized and systematic manner and establish a foundation for future local agreements and expansion of the system. Standardization can be proactively considered for new technologies implemented in the region.

4.4 SIGNAL SYSTEM HARDWARE INTEGRATION COMPONENTS

Within the Western Wake region, there are roughly an equal number of signals in the Town of Cary as there are in the Towns of Apex, Fuquay-Varina, Holly Springs, and Morrisville combined. So from a Western Wake County regional standpoint, roughly the same cost is involved with transition to either platform. However, from a Triangle regional standpoint, all other municipalities that border Western Wake (Raleigh, Durham, Garner, etc.) are standardized on the 332/336S cabinets. NCDOT does not recommend transitioning any additional systems to the NEMA TS-2 cabinet standard as that is moving away from the statewide cabinet standard. Additionally, NCDOT has recently added the Advanced Traffic Controller (ATC) cabinet to the Qualified Products List (QPL). While the features of these ATC cabinets may be the direction of the industry in the future, the Department does not have a definitive plan to migrate toward all ATC cabinets in the near-term. Given these parameters, there are four different options to be evaluated:

1. **Operate a regional mixture of 332/336S and NEMA TS 2 Cabinets.**

   This option is the most likely solution for the near-term until an agreement on standardization and the implementation of a TIP project can be implemented for all municipalities. It is expected that in this scenario, the regional system host will require additional training and efforts to be able to maintain and operate both types of cabinets. Given the amount of effort and additional staff needed, this solution will likely reduce the current efficiency for maintenance.

2. **Convert the Town of Cary signal cabinets to 332/336S.**

   This option would investigate the long-term effort to standardize all cabinets in the region and have the same cabinet as surrounding municipalities to Western Wake. Given the number of current signals in Cary with NEMA TS 2 cabinets, it is expected that this project would require a large TIP project to be implemented. It is also possible that if Cary is not designated as the Regional Host, other agencies in the relationship can partner to standardize their own equipment.

3. **Convert signal cabinets in the Towns of Apex, Fuquay-Varina, Holly Springs, and Morrisville to NEMA-2 Cabinets.**

   Like Option #2, this solution would require a project in the long-term to replace all existing cabinets. NCDOT does not recommend this option. If a portion of the system needed to be turned back over to NCDOT, it would not be in compliance with NCDOT standards.

4. **Replace all cabinets with the new NCDOT-approved Advanced Traffic Controller (ATC) cabinets.**

   This option would be the most expensive and would require the most effort for training since no current system is utilizing them. However, this option would provide new cabinets and equipment to all municipalities in the long-term. This option would advance the region toward newer technology in the industry, use low voltages, and allow an open architecture to integrate with different advanced transportation technologies. However, given the higher cost of these cabinets, this would likely require a series of TIP projects to phase the transition.

Overall, no matter what option is selected, additional training for the regional system host will be required in the near-term to maintain and operate the current equipment in place. During one of the small group meetings with NCDOT, NCDOT offered to assist with additional training and resources for a Regional Host to operate and maintain 332/336S cabinets in the near-term.

Chapter 05
DETAILED OPERATIONS & MAINTENANCE PLAN

5.1 ARTERIAL CORRIDOR OPERATIONS AND MAINTENANCE

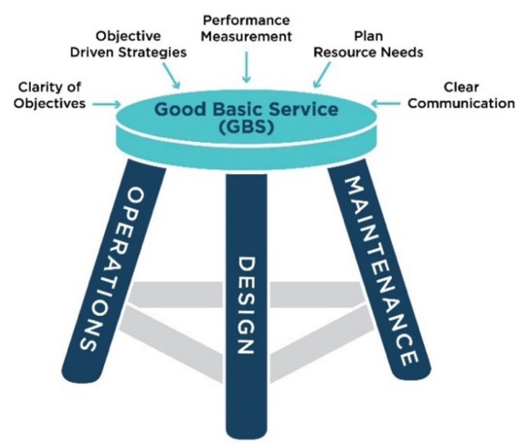
A traffic signal system operations and maintenance plan requires evaluation and documentation of the following elements:

- Define and prioritize operations and maintenance objectives, including level of service to be provided
- Identify current level of performance
- Perform a realistic, objective assessment of current and future agency capabilities
- Align program objectives and agency capabilities
- Determine staffing and resource needs
- Define roles and responsibilities
- Provide for staff training
- Define performance measures
- Identify desired future level of performance along with steps necessary and schedule to attain it
- Identify funding sources (current and potential future)
- Establishing a realistic cost-constrained budget for near, mid, and long-term operations and maintenance goals.
- Establish agreements to define roles, responsibilities, performance measures and cost share among agencies.

The Federal Highway Administration (FHWA) Office of Operations provides a number of practical resources online to assist agencies that design, operate, and maintain traffic signals and signal systems. Development of a traffic signal management program tailored specifically to agency needs is essential to improving traffic signal programs.

GOOD BASIC SERVICE

FHWA defines “Good Basic Service” as doing what’s most important given a set of limited resources. Providing Good Basic Service (GBS) requires balancing design, operations, and maintenance strategies. GBS focuses on results rather than activities when measuring the effectiveness of operations and maintenance. It concentrates on prioritizing limited resources based on an understanding of what’s important to the motoring public and policy makers.



FHWA report FHWA-HOP-09-055, Improving Traffic Signal Management and Operations: A Basic Service Model, explores the GBS concept in great detail, provides case studies, and offers guidance on implementing GBS. View the report here: https://ops.fhwa.dot.gov/publications/fhwahop09055/fhwa_hop_09_055.pdf

The report noted that the following attributes were shared among the successful case studies contained therein:

- Strong concept of basic service
- Clear evaluation of objectives
- Close coordination of design, operations, and maintenance resources and limitations
- Good understanding of measuring results
- Commitment to staff development

TRAFFIC SIGNAL SYSTEM CAPABILITY MATURITY FRAMEWORK

It is crucial that agencies have a realistic understanding of both their capabilities and limitations regarding operating and maintaining traffic signal infrastructure. This understanding helps them set realistic goals and objectives for their program and develop an orderly plan for improving their capabilities and moving their program forward. FHWA's Traffic Signal System (TSS) Capability Maturity Framework (CMF) provides an excellent means for agencies to objectively evaluate their current capabilities and provides numerous action steps to improve capabilities and help agencies to mature to the higher level of capability that they desire.

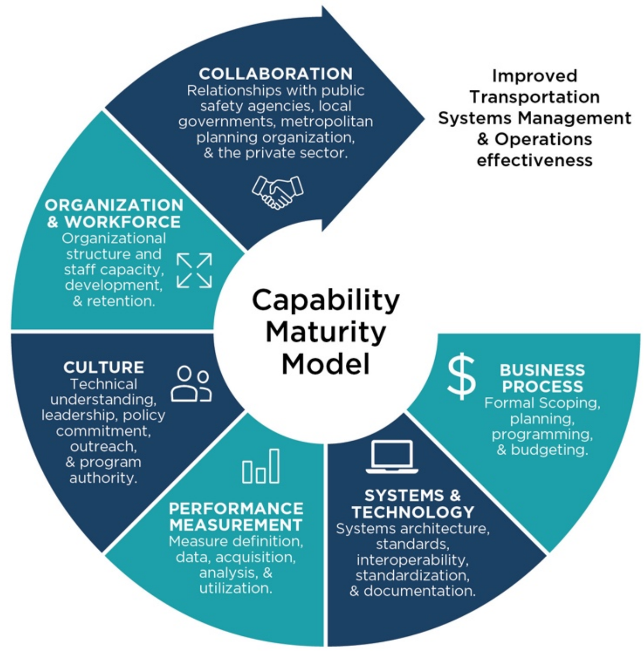
The online TSS Capability Maturity Self-Evaluation Tool will help agencies determine which of the following four levels of capability they fall into. **Table 5.1** identifies the four levels and a few example descriptions for each level.

Table 5.1: Four Levels of TSS Capability

Level 1: **Performed**	Level 2: **Managed**	Level 3: **Integrated**	Level 4: **Optimized**
• Relationships and activities are primarily informal and ad-hoc • Each agency is primarily focused on their individual priorities • Performance measure outputs are not typically reported	• Basic regional consideration is given to strategies, goals, and planning efforts • Processes are developing • Limited regional alignment achieved • Performance measure outputs are easily available	• Regional program alignment • Processes are documented • Systems and technology are standardized and integrated on a regional basis • Performance measure outcomes used for program improvements	• Formal program and partnerships • System integration interoperability maintained continually • Performance measures are reported for accountability and program justification

The tool takes stock of capabilities in the following six dimensions or process areas to ascertain the agency's capability level:

1. **Business Process** – Plans, Programs, Budgets
2. **Systems & Technology** – Approach to Building Systems
3. **Performance Measurement** – Use of Performance Measures
4. **Culture** – Changing Culture and Building Champions
5. **Organization & Workforce** – Improving the Capability of the Workforce
6. **Collaboration** – Improving Working Relationships



REGIONAL, MULTI-AGENCY OPERATIONS

Across the Western Wake region, agencies operate at varying levels of Traffic Signal System maturity. As each agency looks to mature their traffic signal system programs, these next two chapters provide resources and recommendations for traffic signal system operations and maintenance. Using information compiled in Chapters 2 through 4 along with information provided by stakeholders during the SOT and CTT meetings, Chapters 5 and 6 will provide a generalized plan and recommendation for operations and maintenance against those backdrops. As discussed in Chapter 2, the towns of Cary and Morrisville already have an interlocal agreement in place for Cary to operate and maintain several traffic signals within Morrisville. Chapter 5 will focus on further maturing that relationship and system operations, while Chapter 6 will look to define a series of steps to support other agencies that desire to move toward regional standardization.

5.2 CARY & MORRISVILLE CORRIDOR OPERATION COMPLEXITIES

DIFFERING PRIORITIES AMONG CARY, MORRISVILLE, AND NCDOT

An agency's expectations for traffic signal system operations are influenced by several factors. The leadership and executive initiatives, staff capability, citizen involvement, and program funding are but a few of those factors. NCDOT has the broad responsibility to support traffic operations across the state. With a finite number of staff, resources, and funding, the department often partners with municipalities through operations and maintenance agreements (notably called "Schedule C & D") whereby NCDOT reimburses a municipality for the maintenance and operations of State-owned signals within their jurisdiction or surrounding their jurisdictional limits. The Town of Cary currently has Schedule C & D agreements with NCDOT in place. The reimbursement allotment for each municipality is negotiated between the municipality and NCDOT and is payable upon meeting a threshold of providing a Level of Service (LOS) "C" or better. NCDOT defines the varying LOS "A – F" as shown in **Table 5.2** on the next page.

Table 5.2: NCDOT Level of Service for Traffic Signal System Operations

TRAFFIC SIGNAL SYSTEM OPERATIONS					
	LOS A	LOS B	LOS C	LOS D	LOS F
1. Signalized intersections in the Municipality's jurisdiction that are monitored by the system	All	Essentially all: +90%	The vast majority: +80% The only traffic signals not monitored are those whose lack of proximity does not lend them to cost-effective communication	Most: +60% Signalized intersections that are in close proximity to other signalized intersections (<0.5 mile) are in operation but are not monitored by the system	Less than half <50% Signalized intersections that are in close proximity to other signalized intersections (<0.5 mile), are in operation but are not monitored by the system
Signalized intersections that are actively controlled for at least some periods of the day (e.g., timing plans are developed and implemented)	All	Practically all: +95%	The vast majority: +80%	Most: +60%	Most: +60%
2. All timing plans and day plans are evaluated on intervals of:	No greater than six months.	No greater than 12 months	No greater than 18 months	No greater than 24 months	Greater than 30 months
On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified:	Annually	Annually	Annually	On intervals of no greater than 2 years	On intervals of no greater than 2 years
Required new plans are developed and implemented:	Within 3 months of identification	Within 3 months of identification	Within 6 months of identification	Within 12 months of identification	On intervals not to exceed 18 months after identification
3. The Municipality has an active traffic data collection program that includes turning movement counts at all signalized intersections; the collection of average daily traffic counts; and performs travel-time/delay studies on all subsystems: This data is used to evaluate system operations and performance:	At a minimum of every two years	At a minimum of every two years	The Municipality obtains the data that is used to evaluate system operations and performance	The Municipality obtains the data that is used to evaluate system operations and performance	The Municipality does not collect data to evaluate system performance and retime signals. All data used is provided by others
4. Timing plans for newly installed intersections are implemented:	In conjunction with the installation of the traffic signal	In conjunction with the installation of the traffic signal	Within 30 calendar days of the installation of the traffic signal	Within 60 calendar days of the installation of the traffic signal	More than 90 calendar days after installation of the traffic signal

TRAFFIC SIGNAL SYSTEM OPERATIONS					
	LOS A	LOS B	LOS C	LOS D	LOS F
5. The Municipality has an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated on intervals of:	No less than 2 times per year	No less than 2 times per year	No less than 2 times per year	No less than 1 time per year	The Municipality provides emergency restoration only for system communication and hardware components
6. Minimum of all system detectors that are operational at any given time:	90%	85%	80%	60%	50%
The maximum time to repair failed detection devices is:	30 calendar days	30 calendar days	60 calendar days	90 calendar days	120 calendar days
7. The control center is staffed:	By qualified personnel during the AM & PM peak hours, and during other times of high traffic volumes (e.g., special events)	By qualified personnel during the AM & PM peak hours. The operations staff is on-call during other times of expected high traffic volume	By qualified personnel during the AM & PM peak hours. The operations staff is on-call during other times of expected high traffic volume	During either the AM or PM peak hour; whichever is the highest volume period	During either the AM or PM peak hour; whichever is the highest volume period
8. The Municipality uses traffic responsive timing plans where appropriate. Threshold values are evaluated:	Continually	Annually	Annually	The Municipality has not evaluated the use of traffic responsive timing plans	The Municipality has not evaluated the use of traffic responsive timing plans

The Town of Cary holds themselves to a higher expectation for signal performance and has committed to operating their signal system at a LOS A. Morrisville also has an expectation of providing citizens with a high level of service and given the proximity of the two towns, desires that motorists have a seamless experience as they commute or traverse the town boundaries. Cary and Morrisville are aligned with their desire to provide an enhanced level of service for their signalized corridors.

CONSTRUCTION AND DEVELOPMENT IMPACTS ON CORRIDORS

Morrisville and Cary continue to see new traffic signals added with their municipalities, both through roadway projects and new developments. There are two TIP Projects in design that will install fiber along McCrimmon Parkway (U-5747A, let October 2022) and NC 54 (U-5750, let November 2022). As noted in Chapter 3, expanding the fiber optic network will enhance the systems from an integration standpoint and will also enable more efficient maintenance and operations activities.

New development often necessitates the addition of a signal along a coordinated corridor, which requires signal timing analysis and implementation to incorporate the new signal into the corridor. This is necessary to promote both optimal safety and efficient traffic progression.

Construction activities in the vicinity of a signal could have an impact on the signal operations if any of the detectors or cabling are damaged.

For these reasons, it is important to:

- Coordinate development impacts to traffic signals with town planning departments
- Coordinate construction impacts to traffic signals with town planning, engineering, and public works
- Monitor the system to identify issues early and implement necessary traffic system operations modifications

ADVANCEMENT OF TECHNOLOGY

As traffic congestion in urban areas poses a threat to the mobility and efficiency of a traffic signal system, there are continual technology advancements in the industry that aim to improve traffic signal system operations. Municipalities and state DOTs must conduct careful evaluation of new technologies for how they will be used, the benefits they will provide, and how they will integrate with existing systems within the agency and region. Care should be taken such that proprietary systems are given additional attention and evaluation to avoid disparate regional systems that lack interoperability.

A phasing plan for technology deployment is critical both for implementation of technology integration and for developing the systems operations and maintenance program. An operations and maintenance phasing plan will require municipalities to review how the technologies support traffic signal system operations and determine which are critical to providing LOS A operations.

CHANGES IN DESIRED ROLE FOR EACH AGENCY

The Town of Cary is currently responsible for operations and maintenance of the traffic signal system in Cary. They are the owners and operators of traffic signals owned by Cary. Similarly, they have a Schedule C & D Agreement with NCDOT for them to operate and maintain the NCDOT signals within the Town. Both Cary and NCDOT do not wish to make any changes to this current arrangement.

The Town of Morrisville does not have a traffic signal system operations or maintenance crew. Morrisville has an Interlocal Agreement with the Town of Cary for operations and maintenance of many of the NCDOT-owned signals (signals at the intersection of state-owned streets) in Morrisville. Cary uses their Schedule C & D Agreement to receive reimbursement from NCDOT for those signals. Having one entity handle all operations and maintenance between Cary and Morrisville simplifies Schedule C & D management between NCDOT and this single regional system.

There is also an existing Interlocal Agreement between Cary and Morrisville for the operations and maintenance of Town Signals (signals located at the intersection of Town streets). The responsibilities for Cary and Morrisville described within that agreement are as follows:

Town of Cary existing responsibilities:

- Own and maintain fiber optic cable and associated hardware
- Perform utility locates
- Operate and maintain the signals listed in the agreement
- Inspection of newly installed traffic signals

Town of Morrisville existing responsibilities:

- Design and construction of traffic signals, fiber optic cable, and cameras
- Identify intersections for signal operation, permit Cary inspection, permit Cary to operate, notify Cary of a change and permit Cary inspection, provide public easements
- Ownership of traffic signals and other traffic control devices

- Notify Cary of problems
- Agree to not interfere with or change signals or signal timing without Cary approval
- Pay all costs for fiber installation and relocation, when required

At this time only some of the Morrisville signals are under this Interlocal Agreement. Cary and Morrisville are currently working through the development of a new Service Level Agreement and anticipate expanding it to include additional signals within Morrisville.

5.3 CARY AND MORRISVILLE SYSTEM CORRIDOR OPERATIONS PLAN

The Town of Cary has committed to operating their signal system at a high LOS A as defined in its NCDOT Municipal Traffic Operations Agreement (Schedule D). The minimum activities required to maintain LOS A and their minimum frequency are summarized in **Table 5.3** below.

Table 5.3: Operational Activities Required to Maintain LOS A

Minimum Frequency	Activity
Daily / Continuously	1. Staff traffic control center and actively monitor and control system during AM & PM hours and other high traffic volumes/special events. 2. Actively control all signalized intersections during some period of day. 3. Make adjustment to timing plans as warranted by traffic conditions. 4. Use traffic responsive timing plans when appropriate and monitor and update thresholds.
Monthly	1. Repair and restore failed detection devices.
Quarterly	1. Prepare and submit a certified status report detailing the operation of the signal system. 2. Perform preventive maintenance cycles on all traffic signals
Semi-Annually	1. Evaluate all timing plans and day plans. 2. Test and evaluate communications components and central site hardware.
Annually	1. Develop and implement new timing plans for corridors with > 5% growth in traffic volume. 2. Conduct independent financial and compliance of fiscal operations.
Bi-Annually	1. Perform the following traffic data collection: a. Turning movement counts at all signalized intersections. b. Average daily traffic counts. c. Perform travel time/delay studies on all subsystems.

With the existing Interlocal Agreement and pending Service Level Agreement, Cary should expect to maintain LOS A operations while expanding to incorporate the additional signals from Morrisville.

PROPOSED STAFFING APPROACH

The Town of Cary employs three staff that share the responsibility of operating the 219-signal Cary Signal System (including the signals in Morrisville, Apex and one in Holly Springs that Cary currently operates); these staff include a Traffic Engineering Supervisor, a Senior Project Manager, and a Traffic Signal Systems Network Specialist. FHWA's Traffic Signal Operations and Maintenance Staffing Guidelines, dated March 2009, (FHWA-HOP-09-006) recommends a traffic signal system engineering staffing ratio of one traffic engineer per 75-100 signals. These are staff persons responsible for system operations and signal timing. Applying these ratios to the Cary system yields 2.19 to 2.92 traffic engineers. Considering that the Supervisor oversees multiple traffic operations groups and is not focused exclusively on the signal system, the results suggest that Cary's ITS and signals engineering staffing is reasonable for the current number of signals but provides limited capacity to support adding more signals to the system. While current staff should be able to accommodate adding some new Town of Cary signals, adding 14 signals in Morrisville that are not currently in the Cary Signal System may begin to stretch resources and necessitate adding a resource with at least part of their responsibilities devoted to traffic signal system engineering.

Cary's current agreement calls for pro-rata funding of the following engineering/operations positions under Schedule D:

1. Traffic Signal Operations Manager
2. Traffic Signal Systems Operations Engineer
3. Traffic Signal Systems Specialist

Descriptions of the qualifications and essential duties of each position are provided in **Table 5.4** below.

Table 5.4: Qualifications and Duties of Engineering/Operations Staff Positions

Topic	Traffic Signal Systems Operations Manager, or Equivalent	Traffic Signal Systems Operations Engineer, or Equivalent	Traffic Signal Systems Specialist, or Equivalent
Education / Experience	Graduation from a four-year college or university as a major in Civil Engineering or a minimum of 6 years of progressive transportation engineering experience or an equivalent combination of training and directly related experience in traffic signal operations	Graduation from a four-year college or university as a major in Civil Engineering or a minimum of 3 years of progressive transportation engineering experience or an equivalent combination of training and directly related experience in traffic signal operations	Graduation from a two-year college or university or a minimum of 1 year of traffic signal operations experience or an equivalent combination of training and directly related experience in traffic signal operations
Knowledge	Operations experience, knowledge of ITS concepts, data communications, and computerized traffic signal systems equipment	Operations experience, knowledge of ITS concepts, data communications, and computerized traffic signal systems equipment	Knowledge of traffic signal system operations, ITS devices, data communications, and computerized traffic signal systems equipment
Working Knowledge	Working knowledge of principles and practices of traffic signal timing and microcomputer applications of traffic signal optimization software	Working knowledge of principles and practices of traffic signal timing and microcomputer applications of traffic signal optimization software	Working knowledge of principles and practices of traffic signal timing and microcomputer applications of traffic signal optimization software
Soft Skills	Excellent planning and organizational skills, oral and written communication skills, able to make public presentations	Outstanding planning and organizational skills, excellent oral and written communication skills, able to make public presentations	Excellent planning and organizational skills, oral and written communication skills, able to maintain records Attention to detail, respond to condition changes, coordinate work with others
Software	Working knowledge of AutoCAD or MicroStation and PC-Based programs (MS Office, software for traffic optimization and analysis)	Working knowledge of AutoCAD or MicroStation and PC-Based programs (MS Office, software for traffic optimization and analysis)	Working knowledge of AutoCAD or MicroStation and PC-Based programs (MS Office, software for traffic optimization and analysis)
Driver's License	Regular NC Driver's license	Regular NC Driver's license	Regular NC Driver's license

The Town of Morrisville has no existing traffic signal staff, either for engineering or maintenance, and there are no near-term plans to add such positions. The Town's expressed preference is for the Town of Cary to continue management of signal operations. However, as described in Chapter 3, the Town of Morrisville staff are interested in having the capability to monitor CCTV cameras and system operations within Morrisville through the center-to-center communications link between the Cary TMC and the Morrisville Town Hall.

OPERATIONS METHODOLOGIES/TECHNOLOGIES

Operations staff need proper tools to manage the signal system effectively and efficiently and to ensure the signal system provides the desired level of service. The following is a summary of some technologies currently in-use to manage signal system operations and maintenance along with some emerging technologies that will be considered for inclusion in a regional system in the future.

Emergency Vehicle Preemption (EVP)

Emergency vehicle preemption (EVP) technology enhances safety by enabling responding emergency vehicles to preempt traffic signal operations to promote faster response times while reducing conflicts between the emergency vehicle and other vehicles traversing the intersection. For many years, the Town of Cary has used an Opticom coded infrared optical EVP system for fire department vehicles at multiple intersections throughout Cary. The town of Cary is currently transitioning from this infrared EVP system to a new GPS-based EVP system (see "Connected Vehicle" subsection below). The Town of Morrisville does not currently use EVP. However, it may be prudent to consider its usage for mutual aid and incident response, especially as more signals in Morrisville are added to the Cary system. It is important to note that NCDOT does not customarily fund installation, operation, and maintenance of EVP systems, so any such implementation typically requires municipal funding.

Connected Vehicles (CV)

In June 2021, the Town of Cary initiated a project to install Connected Vehicle (CV) technology at all traffic signals, school zone flashers, and crosswalks with rectangular rapid flashing beacons (RRFBs) within the town. In addition, GPS EVP equipment will be installed in Cary Fire Department vehicles and GoCary transit buses. The GPS-based EVP will replace the current infrared optical system discussed above. The equipment added to the GoCary buses will help them stay on-schedule during congested traffic periods (see discussion of Transit Signal Priority that follows below). Applied Information (AI) is the technology provider. Traffic signals and school zone flashers will be able to communicate with motorists, pedestrians, and cyclists via AI's TravelSafely smartphone app using the system's LTE cellular vehicle-to-everything (C-V2X) connectivity.

In addition to the safety enhancements, the AI Field Monitoring Unit installed in the signal controller cabinets record a wealth of information about intersection and signal performance that can help staff operate and maintain the signal system at a high level of service. Reports can be generated from this data to help staff make better informed infrastructure decisions and help with transportation planning. To enable seamless operations across municipalities, it is recommended that the traffic signals in the Town of Morrisville be outfitted with the AI technology as well.

Transit Signal Priority (TSP)

The Wake County Transit Plan calls for construction of about 20 miles of transit lanes along four bus rapid transit (BRT) corridors in Wake County. One corridor extends into Cary to connect downtown Cary and downtown Raleigh. This corridor is known as the Wake BRT: Western Boulevard Corridor, and it is currently in the planning phase. An integral feature of the BRT system is the use of transit signal priority (TSP) technology to enable BRT vehicles to coordinate with traffic signals along their route to extend green times when running behind schedule. The exact TSP system to be used for the design and implementation of the Wake BRT has not yet been determined.

There are some important issues related to TSP implementation along this Raleigh-to-Cary line that must still be worked out as the planning and design for Wake BRT progresses:

1. The Wake BRT line will cross over the boundaries of two independent traffic signal systems, the Raleigh and Cary systems. There would appear to be a need to coordinate traffic signal operations across jurisdictional boundaries.
2. At the present time, the Raleigh and Cary signal systems use different signal controllers, local controller software, and central software.
3. At the present time, the Raleigh and Cary Signal Systems use different hardware and software for TSP.

What is ultimately required for signals along the BRT corridor in Cary needs to be taken into consideration by the Town of Cary in its operations and maintenance plan for the Town's signal system but does not dictate what the Town does regarding all the other non-BRT traffic signals throughout their system.

The Town of Cary also operates fixed-route transit that will benefit from the TSP currently being deployed on buses and at traffic signals.

The Town of Morrisville has a free, on-demand transit system named Morrisville Smart Shuttle rather than a fixed-route, fixed-schedule transit system. The shuttles are owned and operated by GoCary and provide connections to GoCary and GoTriangle bus routes. TSP would not be applicable to an on-demand transit service. While there are no concrete plans at the present time to extend the proposed Wake BRT service westward from Cary into Morrisville, CAMPO has recently launched a study to consider options for expanding the Wake BRT service from the Cary Depot through Morrisville to the RTP. Given the early phase of this study, TSP does not appear to be a major consideration for signals within Morrisville that are currently part of the Cary signal system or may be added to that system in the future.

Integrated Corridor Management (ICM) System

Both the I-40 and US 1 corridors could benefit from an integrated corridor management (ICM) system during major incidents and potentially during peak periods of recurring congestion. A future implementation of ICM would have the capability to redirect traffic to parallel routes in the event of an incident on I-40 or US 1. NCDOT staff who actively monitor traffic conditions on these major regional highways from the State Traffic Operations Center (STOC) could use ICM to dynamically implement actions in response to incidents observed. This would include implementing special signal timing plans and messaging on a system of dynamic message signs and changeable trailblazer signs to divert traffic from I-40 and US 1 to parallel routes and return them to these highways once past this incident. The development, management, and maintenance of ICM would require integration and coordination with NCDOT as well as an increased level of timing plan maintenance along these corridors. NCDOT recently deployed an ICM system along I-85 through Gastonia and it is being incorporated in the current upgrades being designed for the Gastonia Signal System.

Automated Traffic Signal Performance Measures (ATSPM*)*

FHWA's "Evaluating the Benefits and Costs of Implementing Automated Traffic Signal Performance" defines automated traffic signal performance measures (ATSPMs) this way:

> *ATSPMs are a suite of visual aids and data analysis tools combined under a single platform to: 1) collect high-resolution traffic signal and detection data, 2) derive relevant performance measures, and 3) visualize those measures in a format that helps traffic signal staff to operate, maintain, and manage traffic signals to improve safety, mobility, and efficiency of signalized intersections for all users.*

According to FHWA's Everyday Counts ATSPM Fact Sheet, key benefits of ATSPM include:

- **Targeted Maintenance**. ATSPMs provide the actionable information needed to deliver high quality service to customers, with significant cost savings to agencies.
- **Improved Operations**. Active monitoring of signalized intersection performance lets agencies address problems before they become complaints.
- **Increased Safety**. A shift to proactive operations and maintenance practices can improve safety by reducing the traffic congestion that results from poor and outdated signal timing

ATSPM promotes a proactive, performance-based approach rather than the traditional reactive approach to traffic signal operations. Signal retiming can be based directly on actual performance rather manually collecting traffic data and modeling traffic flow and signal operations using traditional traffic analysis and simulation software.

NCDOT has a long-term goal of upgrading all NCDOT signal systems to be ATSPM capable, which led to the development of the "NCDOT Automated Traffic Signal Performance Measures (ATSPM) Implementation Plan", dated 2019. This implementation plan identifies the Open Source ATSPM Software as NCDOT's software of choice. Key requirements for implementing ATSPM include:

- Server storage capacity must be increased substantially to house and process the high-resolution data;
- Additional vehicle detection at signalized intersections beyond traditional NCDOT detection schemes. While the existing NCDOT standard detection layouts would allow for critical ATSPM implementation such as mainline Purdue Coordination Diagrams and sidestreet Purdue Split Failure analysis, additional detection would be required to make full use of all ATSPMs;
- Signal controllers must be 2070LX or another ATSM capable model and equipped with an ATMSPM-capable local controller software to support collection of high-resolution data.

PERFORMANCE EVALUATION METRICS AND STANDARDS

The towns of Cary and Morrisville are both determined to strive for level of service A for their traffic signal operations and maintenance. Meeting or exceeding LOS C operations is a prerequisite to receiving pro-rata reimbursement from NCDOT. Like most traditional plans for operating and maintaining traffic signals, Schedule D is focused on performing specific activities. While performing these activities are based upon and support the intent to provide reliable, predictable performance of the signal system, they do not actually measure and evaluate system performance—that is, the outcome. While the activities are important and necessary, the concept of GBS highlighted at the beginning of this chapter focuses on measuring and evaluating the results of those activities. GBS focuses on the agency's desired outcome.

Some examples of outcome-focused performance measures from FHWA report FHWA-HOP-09-055, *Improving Traffic Signal Management and Operations: A Basic Service Model,* include:

- Total travel times
- Travel time reliability
- Smoothness of flow (versus simply reduction in delays)
- Signal operations that are predictable and consistent
- Rate and type of citizen complaints

Such performance measures should consider what matters most to the traveling public and what impacts their perceptions of signal system performance. Measuring and evaluating these performance measures, and making corresponding adjustments to the system, enable the agency to substantiate their program and the taxpayers' investment in the signal infrastructure. Having this data can support building the case for ongoing, sustainable funding and infrastructure and staffing investments.

Ultimately, the Cary Signal System should move toward implementing Automated Traffic Signal Performance Measures (ATSPM) to facilitate data collection for both improvement of operations and maintenance as well as performance management, which will ultimately lead to providing good basic service.

5.4 CARY & MORRISVILLE INFRASTRUCTURE MAINTENANCE COMPLEXITIES

DIVERSE TRAFFIC SIGNAL CABINET EQUIPMENT

Maintaining traffic infrastructure is much like maintaining many other types of equipment; the more closely maintenance staff know and work with the equipment, the more efficient that maintenance becomes. As noted in the previous chapters, within the Cary and Morrisville area of the region, there are two existing traffic signal cabinet types in use. The Town of Cary standard cabinet is the NEMA TS 2 while the NCDOT standard cabinet is the 332/336S. Operationally, the integration of traffic signal systems using two different cabinets is achievable. From a maintenance standpoint, it is also doable but would require maintenance personnel to be trained on both cabinet types as well as necessitate keeping varying equipment in stock for both cabinets. While it may not be the most efficient or convenient, it could be done. Given the remaining parts of the region and the state have NCDOT standard 332/336S cabinets, it would not be advantageous to transition the entire region away from the 332/336S cabinet. However, two upcoming TIP projects that NCDOT will construct within the Town of Morrisville's municipal limits are planning to utilize Cary's NEMA TS 2 cabinets for the signalized intersections located within their project limits. NCDOT has recently added the Advanced Traffic Controller (ATC) cabinets to their Qualified Products List (QPL) but does not currently have any plans to make a large transition away from the 332/336S cabinet in the near future. If the Town of Cary desires to keep the NEMA TS 2 cabinet as the standard cabinet, there will need to be maintenance capability for maintaining two cabinet types for at least the near-term.

Whether the cabinet types are the same or different, the additional signal system equipment should move toward a standardization of equipment. Of the existing signals in the region, there are some in the Town of Cary that already have technology installed that has not yet been deployed to all signals. The Town should continue the upgrade at existing signals when any modification is performed. Additionally, as Cary integrates more of Morrisville signals into their system, those signals should also be upgraded to the same technology standards. The current Town of Cary standards at the time of this document include:

- Monocurve mast arms are the default structure type.
    - Metal strain poles are considered when mast arm lengths exceed 65'.
    - Poles will be architectural in downtown Cary.
- CCTV cameras are to be provided at all new installations and added to existing locations when modifications are performed.
    - Axis-branded cameras are required. Current model type must be provided.
- Communication is achieved via fiber optic connection using IP communication.
    - Communication must successfully be made and maintained to the TOC ATMS.
    - IP switches must be provided and installed as a part of any new installation.
    - Town of Cary IT Department will program all switches.
    - Expansion of existing fiber optic network is required of all new installations.
- Cabinets are required to be NEMA TS 2
- Controllers must use ASC3 local software
    - 1C boards are required
- Applied Information (AI) Field Monitoring Unit and associated cellular communications equipment.
- Combination meter bases are required at all new installations.
- Right-of-way must be provided on all approaches of an intersection to allow for maintenance of the cabinet, poles, and detection devices.
- Flashing Yellow Arrow (FYA) phasing is required for all left-turn movements.
    - TOD programming is required for all locations with 4-section FYA heads.

- Pedestrian accommodations must be provided if pedestrian facilities are present.
  - LPI programming is required for new pedestrian crossings
  - APS should be provided.
  - R10-15 signs to be provided for approaches with noted pedestrian crossings.
- W3-3 (Signal Ahead) signs are required in advance of the intersection for all approaches.
- Overhead Street Name Signs
  - Standard 18" Blank Green w/White Border
  - 12" Capital Letters
  - 9" Lower Case Letters
  - Not to Exceed 96"

As noted in the previous section, evaluation of new technologies should be done communally and with consideration of the other equipment and system types with which it will integrate. Moving forward, the agreement between Cary and Morrisville should require consensus on any new technology deployed.

DIFFERING MAINTENANCE PRIORITIES AMONG CARY, MORRISVILLE, AND NCDOT

As with operations, NCDOT is also responsible for maintenance of traffic signals on state-owned streets. When an agency has entered into a Schedule C Agreement with NCDOT for performing the maintenance of state-owned signals, NCDOT requires a minimum of maintaining a "good" level of service. NCDOT defines a "good" level of services as follows:

Key Components of a "Good" Level of Service:

1. **Maximum Emergency Response Times**
   - Trouble calls: 4 hours
   - Repair Knockdowns: 8 hours
   - Absence of a signal indication: next working day
   - Repair/replace inoperative loops: 15 calendar days
2. **Operational Performance Reviews**
   - Perform the required minimum tasks at 6-month, 12-month, and two-year intervals
   - Replace LED modules after 5 years of service
3. **System Component Repairs**
   - Repair equipment in a timely manner to support emergency and operational needs
   - Upgrade equipment firmware as appropriate to address items affecting operational efficiency and safety
   - Certify the proper operation of conflict monitors/malfunction management units on an annual basis

While the Schedule C Agreement does not define components for higher levels of service, Cary takes a proactive approach to maintenance activities to ensure the seamless operations required to provide the high operational service their citizens expect. A typical intersection checklist for the Preventive Maintenance activities Cary conducts is included in the Appendix. Agreed-upon expectations for maintenance activities and components among each agency is imperative for a regional system when maintained by one agency.

TRAINING FOR MAINTENANCE STAFF

Traffic Signal System maintenance staff qualifications have traditionally leaned toward mechanical and electrical knowledge. While some agencies require an IMSA Traffic Signal Certification, not all do. In many cases, knowledge of electrical standards, codes, practices, and repair techniques are more heavily weighted. While on-the-job training is imperative, there are also some vendors that offer training courses for specific hardware and/or software. NCDOT will periodically host these trainings, particularly where a new traffic signal system has been constructed, and municipalities are encouraged to attend. STIP projects for construction of ITS systems and signal systems may provide additional opportunities to train staff. NCDOT routinely requires the contractor to provide robust training for multiple municipal and NCDOT personnel as part of every municipal signal system construction contract and some ITS construction projects.

As the traffic signal system industry evolves and is now taking on the shape of more robust networks, incorporating fiber optic network or Ethernet training courses has become more important to the operations and maintenance of these systems. Partnering with IT departments is more commonplace with transportation departments now. Agencies should build on that partnership and seek opportunities to conduct joint training sessions for network operations and maintenance.

5.5 CARY & MORRISVILLE INFRASTRUCTURE MAINTENANCE PLAN

The Town of Cary maintains all traffic signals in the Cary Signal System, including signals in Morrisville, Apex, and Holly Springs that have been incorporated into the Cary system. NCDOT Division 5 maintains isolated signals that are not part of the Cary system as well as signals in standalone arterial closed-loop signal systems in Morrisville, Apex, Fuquay-Varina, and Holly Springs. The Town of Cary maintains NCDOT traffic signals within its system in accordance with a Municipal Operations Agreement with NCDOT. NCDOT reimburses eligible maintenance expenses incurred by the Town to maintain each signal at Level of Service (LOS) C (i.e., "good") condition in accordance with Schedule C of the Municipal Operations Agreement. NCDOT pays no reimbursement if signal maintenance falls below LOS C and does not reimburse additional costs for maintaining signals at higher than LOS C.

The Town of Cary has committed to and invested in maintaining signals in the Cary Signal System at a higher level in response to the expectations of its citizens. The citizens of Morrisville have expressed similar high expectations, hence the Town of Morrisville desires to increase the LOS provided by all of their traffic signals to the same level of service provided by the Town of Cary. To that end, the Town of Morrisville has expressed their desire to incorporate all signals within their limits into the Cary Signal System to be operated and maintained by the Town of Cary.

The Schedule C Agreement contains detailed Operational Performance Checklists of preventive maintenance activities to be performed at specified intervals in order to maintain "good" LOS C. These preventive maintenance activities and their intervals are summarized in **Table 5.5** on the following page. Refer to the Appendix for the full Schedule C checklists as are included in municipal agreements.

Table 5.5: Preventive Maintenance Activities to Maintain LOS C

Required Interval	Preventive Maintenance Activity
6 months	**Operational Performance Reviews:** • General cabinet preventive maintenance • Verify malfunction management unit (MMU) or conflict monitor (CM) certification is within 12 months • Inspect load switches • Inspect relays • Check terminal connections • Verify controller settings, programming, software version, operations, phasing and displays, preemption circuits, check harnesses and connections. • Inspect detection sensors and detector units • Check pedestrian pushbuttons • Inspect condition, alignment, and operation of signal heads. • Check mounting height of vehicle signal heads. • Inspect condition, alignment, and operation of vehicle signals • Inspect wood poles, span wires, guys, and grounding • Check condition of pavement markings and verify that they match signal plan
12 months	**Operational Performance Reviews:** • Test police panel switches • Perform field check of MMU/CM operation. • Replace LED modules in pedestrian signals if necessary • Inspect metal poles and mast arms • Inspect pull boxes (i.e., junction boxes) • Inspect systems equipment • Visually inspect conduits and repair as needed
2 years	**Operational Performance Reviews:** • Clean lenses, LED modules and reflectors in signal heads; replace LED modules as needed; clean signs • Check span wire and signal mounting hardware for wear. • Perform travel time/delay studies on all subsystems.
5 years	Replace LED modules

In addition to the preventive maintenance schedule summarized above, the Town of Cary must meet the following emergency maintenance response times to satisfy "good" LOS C per Schedule C:

Table 5.6: Emergency Response Times for LOS C

Maximum Emergency Response Times	Activity
4 hours	Trouble calls
8 hours	Repair knockdowns
Next working day	Absence of signal indications
15 calendar days	Repair/replace inoperative loops

As noted, these are required to maintain "good" LOS C. The Town of Cary increases their preventive maintenance cycles to once every 3 months rather than once every 6 months, thus increasing the level of service above the required standard. As the Town of Cary integrates signals from another agency, they expect to provide the same high level of maintenance service. The documented procedures and checklist Cary follows for enhanced maintenance activities should be reviewed by Morrisville to ensure all are in agreement with the expectations. These checklists as provided by Cary are included in the Appendix.

PROPOSED STAFFING APPROACH

The Town of Cary has four two-person crews to maintain the 219-signal Cary Signal System (including the signals in Morrisville, Apex and one in Holly Springs that Cary currently maintains). Three of these crews are comprised of a Senior Traffic Signal System Technician and a Traffic Signal System Technician 2. The other crew is comprised of a Traffic Sign and Signal System Technician. Each of these crews are supervised by the Traffic Operations Field Supervisor. FHWA's *Traffic Signal Operations and Maintenance Staffing Guidelines*, dated March 2009, (FHWA-HOP-09-006) recommends maintenance staffing levels of 30-40 signals per technician. Since Cary strives for the highest LOS, the lower number is used for staffing calculations, yielding a requirement of 7.33 technicians. While Cary has 8 technicians, signing is the primary duty of one of the technicians on a crew. This suggests that Cary's maintenance staffing is reasonable for the current number of signals but provides little capacity to support adding more signals to the system. While current staff might be able to accommodate adding a few new Town of Cary signals, adding the 14 signals in Morrisville that are not currently in the Cary Signal System would make it necessary for Cary to hire an additional signal maintenance technician.

The Town of Morrisville is not looking to provide maintenance staffing support from their personnel; however, they do intend to provide secondary signal maintenance space in the new Public Works Facility under design. This will enable Town of Cary signal technicians to service and respond to signals in the western part of the Cary system by reducing the distance they must travel to reach those outlying intersections.

The Town of Cary currently owns four bucket trucks with a 35-foot working height plus three crew cab pickup trucks for maintaining traffic signals. With the addition of a signal maintenance technician as discussed above, the Town should consider adding a pickup truck with service body and lift gate to its signal maintenance fleet.

MAINTENANCE METHODOLOGIES/TECHNOLOGIES

Similar to how operations staff use a series of tools to manage a signal system effectively, there are tools that support the maintenance of the system as well. The following is a summary of how such software may aid in the maintenance of the signal system.

Network Management Software

Signal system communications networks have become too large and complex to manage manually. Network management software (NMS) enables proactive, real-time monitoring of the entire network infrastructure. The NMS monitors the network for device and communications failures, network performance issues, load balancing, bandwidth usage, and many other diagnostics. It provides automatic alerts via graphical display, text message and email of problems detected and generated reports on system performance and statistics. NCDOT includes a NMS in the implementation of new traffic signal systems and upgrades to existing systems.

Traditionally, traffic signal systems have utilized communications systems and local area networks (LANs) for computers and servers that are separate from their agency's primary networks. Traffic engineering staff have been able to operate and maintain their standalone networks effectively in conjunction with their other operations and maintenance responsibilities. However, these networks and their electronic components have increased in complexity for configuration and security of the network. Hence, increased staff time is needed for network management as well as for training to stay current on these technology changes and the expertise they require. Even with tools like NMS, trying to keep up with the pace of technological change in network management while carrying out the primary duties of managing the signal system stretches limited staff resources. As a result, some traffic engineering staff are having to rely more often on support from their municipal IT department who maintain the requisite specialized expertise and who are able stay informed and trained with regard to the latest developments in network technology and cybersecurity.

The Town of Cary in recent years has grown to depend on such part-time assistance from personnel from the town's IT department, although recent IT staffing shortages have limited that support. The town envisions the need for one full-time equivalent staff member who is solely responsible for managing the traffic signal system communications network, CCTV network, and other ancillary devices in those systems along with handling coordination with the Town's IT Department.

Fiber-Optic Cable Asset Management

Implementation of a fiber-optic cable asset management system enables a digital record of the signal systems fiber-optic communications cable plant. These systems support accurate underground utility locating, effective maintenance of cable, and aids in planning for future additions and improvements to the communications network. The Town of Cary currently records information regarding the signal system fiber-optic communications cable network in the Town's GIS. There are both commercial and home-grown GIS software packages available that aid in mapping and tracking these assets, tracing fiber connectivity throughout the system, and providing strand-level management of the cables.

Maintenance Management Software

A maintenance management system allows the maintaining agency to create, schedule, prioritize and track work orders. These systems can also house helpful data about devices and assets such as age, drawings, and manuals. Additionally, keeping record of life-cycle history will support planning and budgeting for repair and replacement costs. These systems also exist as both commercial and home-grown packages.

Chapter 06
HIGH-LEVEL OPERATIONS & MAINTENANCE PLAN

Where Chapter 5 described the integration of the signals in Morrisville and Cary, Chapter 6 will provide information for the towns of Apex, Fuquay-Varina, and Holly Springs to consider as each evaluates their respective desires to advance their traffic signal system operations and maintenance.

6.1 REGIONAL SYSTEM ARTERIAL CORRIDOR OPERATION COMPLEXITIES

At the present time, the towns of Apex, Holly Springs, and Fuquay-Varina do not operate or maintain any traffic signals. NCDOT Division 5 personnel operate and maintain all signals in Apex, Holly Springs, and Fuquay-Varina, except for 7 signals (6 in Apex + 1 in Holly Springs) that are part of the Cary signal system.

NCDOT also owns and maintains most of the communications infrastructure for signals in closed-loop systems in these three towns, but the Town of Holly Springs has been building out a municipal fiber-optic communications network to provide communications to the signals within Holly Springs.

As the region advances traffic signal system programs, each of these towns will be considering the best path forward. Four scenarios related to Signal System Operations and Maintenance (O&M) were considered through stakeholder workshops.

1 NCDOT O&M +

- NCDOT continues to provide standard maintenance and operations activities for state-owned signals
- Municipality is responsible for municipal-owned signals
- Municipality hires out interim corridor re-timing as often as they like (to supplement the current NCDOT schedule for corridor re-timing)

2 Cary Hosted Regional System

- Municipality enters into an agreement to have Cary manage maintenance and operations activities for their signals
- Each municipality pays Cary for O&M

3 Regional System(s)

- Municipalities (2-3) join together to co-manage a signal system (collectively maintain and operate signals)
- Would need to identify a Host agency
- Host agency would be responsible for standing up a Traffic Management Center (TMC)
- Municipalities would pay their portion of O&M cost to the Host agency

4 Individually Managed System(s)

- Each municipality is responsible for signals in their jurisdiction.
- Each municipality stands up a TMC and in-house signal system maintenance and operations division

Scenario 1 would be the most like today's scenario; where NCDOT would continue O&M of state-owned signals, the Town would be responsible for Town-owned signal O&M, but the Town would also seek additional contract work for corridor re-timing at more frequent intervals than is currently done.

Scenario 2 is similar to the collaboration between Cary and Morrisville today. It is understood the Towns of Cary and Morrisville will continue collaboration under this scenario. Apex, Fuquay-Varina, and Holly Springs could evaluate joining this collaborated effort.

Scenario 3 would be evaluated by Apex, Fuquay-Varina, and Holly Springs also. This scenario would function similar to Scenario 2 but may be attractive if any of these three municipalities is interested in being a "Host" (meaning they would establish and staff a fully functioning Traffic Management Center (TMC)).

Scenario 4 could be evaluated by Apex, Fuquay-Varina, and Holly Springs if all three of the municipalities were interested in establishing and staffing a TMC and taking on full O&M responsibilities.

Stakeholders determined Scenario 4 was not cost effective or in the spirit of a regional system. Similarly, Scenario 1 provides marginal maturing of a signal system program and will provide the least change from a regional system perspective. As Apex, Fuquay-Varina, and Holly Springs evaluate Scenarios 2 and 3 more closely, a phased migration will be important since either of these options will include a significant change in responsibilities.

DIFFERING PRIORITIES AMONG AGENCIES

One of the biggest differences in the operations and maintenance management of traffic signal systems that the Town of Cary provides is the LOS maintained. As described in Chapter 5, each agency's priorities for maintaining a traffic signal system vary from one-to-the-next. However, NCDOT's Schedule C & D requirements do not change and any agency that performs operations and maintenance under these agreements is required to maintain LOS "C", or better. Cary defines their service provided as LOS "A". Within Chapter 5, **Table 5.2** defines the variance between LOS "A – F". As Apex, Fuquay-Varina, and Holly Springs evaluate their options, one of the defining differences between the services provided by Cary and required by NCDOT are these LOS criteria. **Table 5.2** should be closely considered to determine each agency's expectations for operations of a traffic signal system. Any town that wishes to pursue Scenario 2 must be committed to providing a higher level of service and accept that doing so comes at a cost.

Some of the input received from each of these towns is as follows:

> **Apex:** predominant number of signals are NCDOT signals that are operated and maintained by NCDOT. There have not been any significant issues with O&M. As the town grows, the instances of signals installed on town streets is more prevalent and necessitates the Town to make accommodations for O&M of those signals. Having very little financial obligation for signal O&M currently will require a demonstrated change of responsibility and identification of benefits for support of marked transportation funding needs. The Town understands that as the number of signals continues to increase, changes are necessary to ensure safe, efficient, and optimal O&M of the traffic signal system.

> **Fuquay-Varina:** all signals are NCDOT signals; operated and maintained by NCDOT. The town has not seen any issues with the level of service provided by NCDOT for O&M. There is an NCDOT TIP project under design for traffic signal system upgrade and fiber optic cable design. The town does not anticipate any near-term addition of Town-owned signals.

> **Holly Springs:** predominant number of signals are NCDOT signals that are operated and maintained by NCDOT. There is one Town signal that is under agreement for Town of Cary to operate and maintain. The Town has installed fiber optic cables along the Town's major streets network which provides the potential of connecting all existing traffic signals in Holly Springs. The long-term goal for the Town of Holly Springs is to operate and maintain their own traffic signal system. However, the Town acknowledges their current capabilities leave a substantial amount of room to methodically plan their steps to mature the signal system program. Regardless of signal system operations, the Town of Holly Springs IT Department will maintain control of all network aspects of a new or expanded signal system within town limits for any traffic signals that the Town would maintain. The Town is currently designing a new public works facility and intends to allocate a portion of that building for the transportation department.

While NCDOT's role is two-fold; NCDOT could provide the O&M for state-owned signals or provide reimbursement through Schedule C&D Agreements. At the present time NCDOT is not able to provide more funding for operations and maintenance than they currently are through Schedule C&D reimbursements. Any cost beyond these reimbursements would be for each municipality to bear.

CONSTRUCTION AND DEVELOPMENT IMPACTS ON CORRIDORS

As mentioned, new developments throughout a town often lead to new traffic signals. When those signals are on town-owned streets, the signal is town-owned. Agencies seeing much growth are finding the need to add signal expertise or out-source contract work is critical. Other impacts seen from new developments are the new and different traffic patterns requiring the need for more frequent re-timing efforts on certain corridors.

ADVANCEMENT OF TECHNOLOGY

Technology is instrumental to traffic operation systems. As noted previously, municipalities and state DOTs must conduct careful evaluation of new technologies for how they will be used, the benefits they will provide, and how they will integrate with the existing systems an agency is running. For regional integration, it will also be important to evaluate all new technologies for their ability to integrate with systems running in the region. To standardize with the region, it will be important to keep technology standards up with the most advanced agency in the region. It is recommended to conduct quarterly/routine regional meetings to evaluate advancing technologies. The Regional ITS Working Group, which is in its infancy, is an ideal group to be discussing the technology trends in the industry.

CHANGES IN DESIRED ROLE FOR EACH AGENCY

As identified in the scenarios above, there are varying roles for each agency depending on the scenario. With Scenario 2, Apex, Fuquay-Varina, and Holly Springs would need to be looking to provide the same level of service Cary provides to its citizens and would need to negotiate an agreement that would provide reimbursement to Cary should they decide to extend their traffic signal O&M program. Cary would also need to evaluate the impact of expanding their program to ensure there is no loss of productivity, efficiency, or level of service to the citizens of Cary.

There is an existing agreement between Cary and Holly Springs for the operations and maintenance of one Town of Holly Springs signal. The responsibilities for Cary and Holly Springs described within that agreement are as follows:

Town of Cary existing responsibilities:

- Operate signal
- Notify Holly Springs if it cannot operate a signal
- Maintain and operate the covered signals

Town of Holly Springs existing responsibilities:

- Provide all services necessary for signal installation
- Provide all necessary sub-surface utilities exploration survey and structural design reviews
- Provide Cary with access to at least one storage area and materials necessary for signal maintenance
- Own signal, equipment, and devices
- Notify Cary of problems
- Not interfere with signal or change timing
- Pay for all fiber relocation work
- Pay Cary signal operation fees annually
- Provide traffic control measures

For future operations, Holly Springs and Cary can evaluate renewal of this agreement should that be the desired path forward. Similarly, Apex and Fuquay-Varina will consider the scenario that best suits their needs.

Since Holly Springs has identified long-term goals of signal system operations, they may be best suited to become a Regional Host as described in Scenario 3. Closer attention to the details involved with that are discussed in subsequent sections of this chapter.

6.2 REGIONAL SYSTEM ARTERIAL CORRIDOR OPERATIONS PLAN

The operational differences between Scenarios 2 & 3 are that Cary provides LOS A and NCDOT requires a minimum of LOS C; therefore, the scope of services for arterial corridor operations between agencies can be assessed along two tiers: LOS A criteria and LOS C criteria. The Regional Host and all municipalities within the designated operational area can determine which criteria is suitable for the needs of the public based upon citizen expectations and available resources, such as funding and staffing.

To achieve LOS A along an arterial corridor, more resources are required. NCDOT maintains a goal of LOS C for its signal operations, which requires less resources than LOS A. LOS criteria for both A and C are summarized below and are based on a typical NCDOT Traffic Operations Agreement (Schedule D).

The minimum activities required to maintain LOS A and their minimum frequency are summarized in **Table 6.1** below. Refer to the Appendix for detailed Schedule D requirements concerning LOS as well as operations staffing roles/responsibilities.

Table 6.1: Minimum Activities Required by NCDOT to Maintain LOS A

Minimum Frequency	LOS A Activity
Daily / Continuously	1. All (100%) of signalized intersections monitored by the system. 2. Staff traffic control center and actively monitor and control system during AM & PM hours and other high traffic volumes/special events. 3. Actively control all signalized intersections during some period of day. 4. Make adjustment to timing plans as warranted by traffic conditions. 5. Use traffic responsive timing plans when appropriate and monitor and update thresholds. 6. Ensure 80% of system detectors are operational at all times.
Monthly	1. Repair and restore failed detection devices.
Quarterly	1. Prepare and submit a certified status report detailing the operation of the signal system.
Semi-Annually	1. Evaluate al timing plans and day plans. 2. Test and evaluate communications components and central site hardware.
Annually	1. Develop and implement new timing plans for corridors with > 5% growth in traffic volume. 2. Conduct independent financial and compliance of fiscal operations.
Bi-Annually	1. Perform the following traffic data collection: a. Turning movement counts at all signalized intersections. b. Average daily traffic counts. c. Perform travel time/delay studies on all subsystems.

The minimum activities required to maintain LOS C and their minimum frequency are summarized in **Table 6.2** below. Refer to the Appendix for detailed Schedule D requirements concerning LOS as well as operations staffing roles/responsibilities.

Table 6.2: Minimum Activities Required by NCDOT to Maintain LOS C

Minimum Frequency	LOS C Activity
Daily / Continuously	1. At least 80% of signalized intersections monitored by the system. 2. Staff traffic control center and actively monitor and control system during AM & PM hours. Staff is on-call during other high traffic volumes/special events. 3. Actively control 80% of signalized intersections during some period of day. 4. Make adjustment to timing plans as warranted by traffic conditions. 5. Use traffic responsive timing plans when appropriate. 6. Ensure 80% of system detectors are operational at all times.
60 days	1. Repair and restore failed system detection devices.
Quarterly	2. Prepare and submit a certified status report detailing the operation of the signal system.
Semi-Annually	1. Test and evaluate communications components and central site hardware.
Annually	1. Develop and implement new timing plans for corridors with > 5% growth in traffic volume. 2. Update traffic responsive timing plan thresholds. 3. Conduct independent financial and compliance of fiscal operations.
18 months	1. Evaluate all timing plans and day plans.
Bi-Annually	1. Obtain traffic data used to evaluate system performance.

To achieve these criteria, the participating municipalities must have a signal system in place and the corridors must be clearly defined and established. The boundaries of the arterial corridors may change in the long term as land use changes or there is significant growth. The equipment including signal cabinets, controllers, and detection devices must be uniform enough to provide a connective service.

TRAFFIC MANAGEMENT CENTER

An important part of establishing effective regional connectivity and operations would be the establishment of a regional TMC. The TMC would serve as the hub for the regional network to allow for primary central system server storage, traffic signal monitoring, incident management, and other key operational equipment. Scenarios 1 and 2 would not require the construction of a new regional TMC, since either NCDOT or Cary would manage the maintenance and operations and each already have an established TMC.

For scenario 3, a TMC should be built in the jurisdiction identified as the regional host. The regional host would need to allocate space within a facility adequate for serving traffic operation management needs. The ideal geographic location of the TMC would be a location that provides reasonable connectivity to the nearby systems. The functional and operational uses and needs of the TMC should be evaluated collectively among all agencies that will be using the facility.

TMCs have traditionally included a large viewing wall with an array of video displays for mapping, performance data and live video. Some agencies have seen a shift from using a full video wall to desiring more functionality at each operator’s workstation. Discussing how the involved agencies will utilize the TMC will be important to identifying the best solution for the regional agreement.

Since the TMC space is most likely to be identified within an existing Town building, standard facility needs such as restrooms, break rooms, parking, etc. are not identified here.

The TMC space requirements specific to traffic operations activities would include the following:

- A server room with conduit from an external demarcation point to the server room.
- Server rack space to accommodate at least 4 standard size equipment racks. Adequate space for rack door-swing as well as room to move around the racks must also be factored into the space needs.
- Storage space for equipment related to the signal system, CCTV video server and other communication devices such as switches.
- Operator Workstations – consider that each operator will need multiple monitors (typically 2-4 monitors)
- Video Wall System – similar systems typically use 45-55" monitors in arrays of 2x3 to 2x6
- Layout space/table for collaborative worksessions
- Adjacent Conference Room (with windows for viewing video wall if desired)
- Adjacent Supervisor Office Space

For Scenario 4, since each municipality would be responsible for their own operations and maintenance, each municipality would need to establish their own TMC. Guidelines for space requirements would be the same, however, scalable to each agencies individual size.

PROPOSED STAFFING APPROACH

FHWA's Traffic Signal Operations and Maintenance Staffing Guidelines, dated March 2009, (FHWA-HOP-09-006) recommends traffic signal system engineering staffing levels of 75-100 signals per traffic engineer. These are persons responsible for system operations and signal timing. Applying these ratios to a regional system comprised of approximately 170 signals in Apex, Fuquay-Varina, and Holly Springs yields 1.7 to 2.27 traffic engineers. Therefore, it appears that the following two traffic engineering positions would need to be staffed by the Regional Host in the beginning:

1. Traffic Signal Operations Manager
2. Traffic Signal Systems Operations Engineer

Table 6.3 below provides a more detailed breakdown of the possible dedicated staffing needs for the regional system options based on the goal level-of-service. Knowing that Cary strives to achieve the highest level of service, it is assumed their required staffing needs would be on the lower end of the signals/traffic engineer range.

Table 6.3: Regional Staffing Needs Scenarios

Regional Staffing Needs Scenarios				
Regional Scenario	**Approximate # of Signals (Assumed Growth)**	**Current # of Staff**	**Additional # of Staff Needed (at lower end of signals/traffic engineer range)**	**Additional # of Staff Needed (at higher end of signals/traffic engineer range)**
Apex/Fuquay-Varina/Holly Springs	191	0	2.5	2
Cary/Morrisville/Apex/Fuquay-Varina/Holly Springs	453	2	4	2.5* (*any system with Cary O%M will have a higher LOS expectation, therefore likely more staff)

For Scenario 4, individually managed systems, would necessitate a single engineering position for each signal systems operations.

HIGH LEVEL SYSTEM MANAGEMENT METHODOLOGIES/TECHNOLOGIES

Operations staff need proper tools in order to manage the signal system effectively and efficiently and to ensure the signal system provides the desired level of service. The following is a summary of some technologies currently in use to manage signal system operations and maintenance along with some emerging technologies that will be considered for inclusion in a regional system in the future.

Network Management Software

Signal system communications networks and computer networks have become too large and complex to manage manually. Network management software (NMS), sometimes referred to as a network management system, enables proactive, real-time monitoring of the entire network infrastructure. Chapter 5 provided a discussion of NMS features and benefits as well as operations and maintenance staffing for network management.

Fiber-Optic Cable Asset Management

Implementation of a fiber-optic cable asset management system enables a digital record of the signal systems fiber-optic communications cable plant. These systems support accurate underground utility locating, effective maintenance of cable, and aids in planning for future additions and improvements to the communications network. The Town of Holly Springs currently records information regarding the signal system fiber-optic communications cable network in the Town's GIS. There are both commercial and home-grown GIS software packages available that aid in mapping and tracking these assets, tracing fiber connectivity throughout the system, and providing strand-level management of the cables.

Emergency Vehicle Preemption (EVP)

Emergency vehicle preemption (EVP) technology enhances safety by enabling responding emergency vehicles to preempt traffic signal operations to promote faster response times while reducing conflicts between the emergency vehicle and other vehicles traversing the intersection. The towns of Apex and Fuquay-Varina do not utilize EVP at the present time. The town of Holly Springs uses an Opticom coded infrared optical EVP system for fire department vehicles at selected locations in Holly Springs. The traditional EVP technology used for many years is the Opticom infrared system used by the town of Holly Springs and also by the Town of Cary. However, GPS-based EVP systems are becoming increasingly popular as they overcome some of the line-of-sight limitations of optical systems. In fact, the town of Cary is currently transitioning from their Opticom infrared EVP system to a new GPS-based EVP system that is integral to deployment of connected vehicle (CV) technology throughout Cary. Usage of EVP technology is typically a municipal preference and is not required to have a traffic signal system that functions at a good level of service. It is important to note that NCDOT does not customarily fund installation, operation, and maintenance of EVP systems, so any such implementation typically require municipal funding. If Apex and Fuquay-Varina do elect to deploy EVP technology, it would be advisable to use the same technology throughout the regional system to which they belong to simplify operations and maintenance of the regional system.

Connected Vehicles (CV)

Some discussion of Connected Vehicle (CV) technology is found in Chapter 5, specifically in the context of the Town of Cary's current project to deploy CV technology town wide. Cary's would be the first system-wide deployment of CV technology in North Carolina. NCDOT has supported limited deployment along specific test-bed corridors as part of signal system upgrade projects for the City of Durham and the City of Greenville. CV technology does not have to be deployed as part of an initial signal system roll-out, but the signal system infrastructure to support CV technology should be part of the initial signal system construction.

Transit Signal Priority (TSP)

Transit signal priority (TSP) technology enables transit vehicles, typically buses, to coordinate with traffic signals along their route to extend green times when they are running behind schedule. The Town of Apex is set to launch its first local transit route, GoApex Route 1, this Spring. However, the towns of Holly Springs and Fuquay-Varina do not operate municipal transit service at this time. Fuquay-Varina is considering shared, on-demand transit, also known as micro transit. Holly Springs does have a peak-hour bus service between downtown Raleigh and downtown Holly Springs provided by GoTriangle.

TSP would not be applicable to an on-demand transit service, and GoApex is in its infancy with only a single route set to launch soon. There are no plans at the present time to extend the proposed Wake BRT service, which would require TSP, southwestward from Garner to Fuquay-Varina and Holly Springs or from Cary into Apex. It is reasonable to assume that such extensions might be explored at some time in the future after the initial system gets established given the sustained rapid growth in this region of the county and Apex's proximity to the proposed western terminus of the BRT system in neighboring Cary. However, there do not appear to be compelling reasons for implementing TSP within these three municipalities in foreseeable future.

Automated Traffic Signal Performance Measures (ATSPM)

Chapter 5 of this report provides a description of automated traffic signal performance measures (ATSPMs). NCDOT has a long-term goal of upgrading all NCDOT signal systems to ATSPM, which led to the development of the "NCDOT Automated Traffic Signal Performance Measures (ATSPM) Implementation Plan", dated 2019. This implementation plan identifies the Open Source ATSPM Software as NCDOT's software of choice. Key requirements for implementing ATSPM include:

- Server storage capacity must be increased substantially to house and process the high-resolution data.
- Additional vehicle detection at signalized intersections beyond traditional NCDOT detection schemes. While the existing NCDOT standard detection layouts would allow for critical ATSPM implementation such as mainline Purdue Coordination Diagrams and sidestreet Purdue Split Failure analysis, additional detection would be required to make full use of all ATSPMs.
- Signal controllers must be 2070LX or another ATSM capable model and equipped with an ATSPM-capable local controller software to support collection of high-resolution data.

PERFORMANCE EVALUATION METRICS AND STANDARDS

While the towns of Apex, Fuquay-Varina and Holly Springs have expressed long-term aspirations to attain level of service A or B, they feel that LOS C would be a prudent initial goal as they make their entry into signal system operations and maintenance. Their desire is to establish a good foundation through solid performance at LOS C before progressing to LOS B or A. The foundational performance metrics for LOS C that these towns must meet are described in NCDOT Schedules C and D. While an initial LOS C would be an acceptable first step for standalone municipal signal systems or a Apex/Holly Springs/Fuquay Varina regional system, it may not be a sufficient starting point for a Cary-led regional system. The town of Cary has established LOS A as its standard and has indicated that all signals within their system must be operated and maintained at that same high LOS A.

Meeting or exceeding LOS C operations is a prerequisite to receiving pro-rata reimbursement from NCDOT. Like most traditional plans for operating and maintaining traffic signals, Schedule D is focused on performing specific activities. While performing these activities are based upon and support the intent to provide reliable, predictable performance of the signal system, they do not actually measure and evaluate system performance—that is, the outcome. While the activities are important and necessary, the concept of GBS highlighted at the beginning of this chapter focuses on measuring and evaluating the results of those activities. GBS focuses on the agency's desired outcome.

Some examples of outcome-focused performance measures from FHWA report FHWA-HOP-09-055, *Improving Traffic Signal Management and Operations: A Basic Service Model*, include:

- Total travel times
- Travel time reliability
- Smoothness of flow (versus simply reduction in delays)
- Signal operations that are predictable and consistent
- Rate and type of citizen complaints

Such performance measures should consider what matters most to the traveling public and what impacts their perceptions of signal system performance. Measuring and evaluating these performance measures, and making corresponding adjustments to the system, enable the agency to substantiate their program and the taxpayers' investment in the signal infrastructure. Having this data can support building the case for ongoing, sustainable funding and infrastructure and staffing investments.

Ultimately, the Regional Signal System should move toward implementing ATSPM to facilitate providing Good Basic Service.

6.3 REGIONAL SYSTEM INFRASTRUCTURE MAINTENANCE COMPLEXITIES

DIVERSE TRAFFIC SIGNAL CABINET EQUIPMENT

The two different cabinet types in the region have been discussed previously; whether the cabinet types are the same or different, the additional signal system equipment should move toward a standardization of equipment. Chapter 5 identifies the items which the Town of Cary requires for signals. Any agency that partners with Cary for O&M must meet the Town of Cary standards for their signal infrastructure and equipment. If a regional system were built up among Apex, Fuquay-Varina, and Holly Springs there are certain aspects that would need to become standard to ensure seamless integration of the various systems.

The Regional standards each agency should strive toward are:

332A/336S Traffic Cabinets

- 2070LX Controllers with an ATSPM-capable local software
- Vehicle detection along major corridors (regardless of jurisdiction the signals reside in)
- IP fiber optic communications
- CCTV camera installation for high volume, high crash intersections

There are additional signal features used throughout the region which are worth considering from a standardization perspective. These items do not have direct impact on systems' ability to integrate, but they do help create a cohesive appearance for driver expectation for those who traverse town boundaries on a regular basis:

- Flashing Yellow Arrows (FYA) for left-turn movements
- The use of LPI programming and APS where pedestrian facilities are present
- R10-15 signs provided for approaches with noted pedestrian crossings
- W3-3 signs required in advance of the intersection for all approaches
- Overhead Street Signs
    - Standard 18" blank green with white border
    - 12" capital letters
    - 9" lower case letters
    - Not to exceed 96"

As noted previously, evaluation of new technologies should be done communally and with consideration of the other equipment and system types with which it will integrate. Any regional agreements between agencies should require consensus for any new technology being evaluated.

DIFFERING MAINTENANCE PRIORITIES AMONG AGENCIES

NCDOT has a minimum requirement for traffic signal maintenance defined in the Schedule C Agreement as maintaining a "good" level of service. From an integrated system standpoint, it will be important to establish a minimum standard that all agencies must meet. Establishing a set of standards for the region will provide an expectation for maturity that each agency can expect to grow towards. NCDOT defines a "good" level of services as follows:

Key Components of a "Good" Level of Service:

1. Maximum Emergency Response Times
   - Trouble calls: 4 hours
   - Repair knockdowns: 8 hours
   - Absence of a signal indication: next working day
   - Repair/replace inoperative loops: 15 calendar days
2. Operational Performance Reviews
   - Perform the required minimum tasks at 6-month, 12-month, and 2-year intervals
   - Replace LED modules after 5 years of service
3. System Component Repairs
   - Repair equipment in a timely manner to support emergency and operational needs
   - Upgrade equipment firmware as appropriate to address items affecting operational efficiency and safety
   - Certify the proper operation of conflict monitors/malfunction management units on an annual basis

Just as the Town of Cary has done, agencies can set more stringent standards for maintenance activities, but the NCDOT list is the minimum requirement. Agencies will not be reimbursed at an increased rate for holding themselves to a higher standard.

TRAINING FOR MAINTENANCE STAFF

Traffic Signal System maintenance staff qualifications have traditionally leaned toward mechanical and electrical knowledge. While some agencies require an IMSA Traffic Signal Certification, not all do. In many cases, knowledge of electrical standards, codes, practices, and repair techniques are more heavily weighted. While on-the-job training is imperative, there are also some vendors that offer training courses for specific hardware and/or software. NCDOT will periodically host these trainings, particularly where a new traffic signal system has been constructed, and municipalities are encouraged to attend. STIP projects for construction of ITS systems and signal systems may provide additional opportunities to train staff. NCDOT routinely requires the contractor to provide robust training for multiple municipal and NCDOT personnel as part of every municipal signal system construction contract and some ITS construction projects. One such opportunity for training will be during construction of the Fuquay-Varina Signal System (STIP No. U-6022), which is scheduled to be let for construction in February 2023. While Town of Fuquay-Varina staff will certainly be included in such training, perhaps some personnel from the neighboring towns of Holly Springs and Apex could be included as well.

As the traffic signal system industry evolves and is now taking on the shape of more robust networks, incorporating fiber optic network or Ethernet training courses has become more important to the operations and maintenance of these systems. Partnering with IT departments is more commonplace with transportation departments now. Agencies should build on that partnership and seek opportunities to conduct joint training sessions for network operations and maintenance.

6.4 REGIONAL SYSTEM INFRASTRUCTURE MAINTENANCE PLAN

NCDOT Division 5 currently maintains all traffic signals and closed-loop signal systems in Apex, Holly Springs, and Fuquay-Varina except the limited number of signals in Apex and Holly Springs that are part of the Cary system and maintained by Cary. In addition, NCDOT Division 5 will operate and maintain the proposed Fuquay-Varina signals system when construction is completed over the next 3 years or so. NCDOT maintains these signals at LOS C (i.e., “good”) condition as defined in Schedule C. Due to funding and resource constraints, NCDOT cannot commit to maintaining signals at a higher LOS such as LOS B or LOS A like the Town of Cary does.

In order for the towns of Apex, Holly Springs, and Fuquay-Varina to take on maintenance of signals within their respective limits, they will have to enter into a Municipal Operations Agreement with NCDOT to maintain signals at LOS C or better. NCDOT reimburses eligible maintenance expenses incurred by the Town to maintain each signal at Level of Service (LOS) C (i.e., “good”) condition in accordance with Schedule C of the Municipal Operations Agreement. NCDOT pays no reimbursement if signal maintenance falls below LOS C and does not reimburse additional costs for maintaining signals at higher than LOS C.

The Schedule C Agreement contains detailed Operational Performance Checklists of preventive maintenance activities to be performed at specified intervals to maintain “good” LOS C. These preventive maintenance activities and their intervals are summarized in the **Table 6.4.** Refer to the Appendix for the full Schedule C checklists as are included in municipal agreements.

Table 6.4: NCDOT Operational Performance Checklists for Preventive Maintenance for LOS C

Required Interval	Preventive Maintenance Activity
6 months	Operational Performance Reviews: • General cabinet preventive maintenance • Verify malfunction management unit (MMU) or conflict monitor (CM) certification is within 12 months • Inspect load switches • Inspect relays • Check terminal connections • Verify controller settings, programming, software version, operations, phasing and displays, preemption circuits, check harnesses and connections. • Inspect detection sensors and detector units • Check pedestrian pushbuttons • Inspect condition, alignment, and operation of signal heads. • Check mounting height of vehicle signal heads. • Inspect condition, alignment, and operation of vehicle signals • Inspect wood poles, span wires, guys, and grounding • Check condition of pavement markings and very that they match signal plan
Required Interval	**Preventive Maintenance Activity**
12 months	Operational Performance Reviews: • Test police panel switches • Perform field check of MMU/CM operation. • Replace LED modules in pedestrian signals if necessary • Inspect metal poles and mast arms • Inspect pull boxes (i.e., junction boxes) • Inspect systems equipment • Visually inspect conduits and repair as needed

2 years	Operational Performance Reviews: • Clean lenses, LED modules and reflectors in signal heads; replace LED modules as needed; clean signs • Check span wire and signal mounting hardware for wear. • Perform travel time/delay studies on all subsystems.
5 years	Replace LED modules

In addition to the preventive maintenance schedule summarized above, the Towns of Apex, Holly Springs and Fuquay-Varina must meet the following emergency maintenance response times to satisfy "good" LOS C per Schedule C:

Table 6.5: NCDOT Emergency Response Times to Maintain LOS C

Maximum Emergency Response Times	Activity
4 hours	Trouble calls
8 hours	Repair knockdowns
Next working day	Absence of signal indications
15 calendar days	Repair/replace inoperative loops

As noted, these are required to maintain "good" LOS C. If at some later date, the towns desire to maintain signals at a higher LOS at their expense like the Town of Cary, the towns will need to increase maintenance staffing sufficiently to perform maintenance at more frequent intervals and to reduce response times. Alternatively, the Towns could contract with the Town of Cary to maintain their signals at a higher LOS per the Town of Cary's standard practice.

PROPOSED STAFFING APPROACH

The towns of Apex, Holly Springs, and Fuquay-Varina do not maintain any traffic signals at the present time. In order to take on maintenance of individual systems (Scenario 4) or a three-town regional system (Scenario 3), the municipalities would need to add qualified maintenance staff, purchase and outfit signal maintenance vehicles, purchase maintenance tools and supplies, and provide space for a signal maintenance facility (i.e., signal shop).

FHWA's *Traffic Signal Operations and Maintenance Staffing Guidelines*, dated March 2009, (FHWA-HOP-09-006) recommends maintenance staffing levels of 30-40 signals per technician. Since Apex, Holly Springs, and Fuquay-Varina have an initial goal of attaining LOS C, the higher number is used for staffing calculations, which yields the number of full-time equivalent (FTE) maintenance technicians shown in **Table 6.5** below.

Table 6.6: Maintenance Technicians Required to Maintain LOS C

Proposed Signal System	No. of Traffic Signals (*Assumed growth*)	Estimated FTEs Required
Town of Apex	72	1.8
Town of Holly Springs	63	1.6
Town of Fuquay-Varina	55	1.4
Regional System (Scenario 3)	190	4.8

Typically, a Senior Traffic Signal System Technician is paired with a less experienced Traffic Signal System Technician to form a two-person work crew for both safety and efficiency. Where the table above indicates the need for a partial FTE (i.e., part-time technician), some agencies will assign additional duties to that technician to round out the technician's workload. For example, the technician may be classified as traffic signal/signing technician. A Traffic Operations Field Supervisor would supervise the crews.

Traffic signal maintenance vehicles may include bucket trucks, pickup trucks with service bodies, conventional pickup trucks, and an open utility trailer. As a general rule, there should be at least one bucket truck for every two-person maintenance crew. The bucket truck should have a minimum working height of 30 feet for signal maintenance and 40 feet for CCTV camera maintenance (or greater depending on the agency's camera mounting height). Having two bucket trucks is beneficial for stringing messenger cables (span wires) between poles, although a second truck could be borrowed from another town department. There would be at least one pick-up truck with a service body for non-aerial maintenance work. The supervisor would typically have a pickup truck, unless the supervisor also performs field maintenance, in which case, a service truck would be more suitable. Either the service truck or pickup truck needs to be equipped with a lift gate for loading and unloading controller cabinets when transporting them between the shop and the field. There could be variety of uses for a utility trailer, such as transporting traffic control devices for lane closures, transporting materials to a construction or maintenance site, etc.

Using the Regional System as an example, a minimum fleet of signal maintenance vehicles might consist of:

- 2 bucket trucks
- 1 pick-up truck with utility body and lift gate
- 1 conventional pick-up truck
- 1 open utility trailer

Fleet vehicle procurement and maintenance will need to be considered from both a capital and O&M cost perspective.

Additionally, a signal maintenance facility is needed to house the following:

- Test controller and cabinet
- Test CCTV camera and cabinet
- Space for new controller cabinets during burn-in
- Storage for spare equipment and parts as well as tools
- Bench for testing and repair of electronic equipment
- The maintenance supervisor's office
- Meeting/gathering space for maintenance personnel
- Signal system computer workstation

In Scenario 3 where several municipalities pool resources, multiple maintenance facilities may be needed to effectively maintain and operate the signals across municipalities. The Town of Cary currently has a signal maintenance facility to serve the Town's system needs. As agencies move toward the regionally operated and maintained system, suitable site(s) would need to be identified for facilities to house these activities.

NCDOT desires to minimize the number of municipal operations agreements and enter into Schedule C and D Agreements with a single agency. For the regional system, this would be the Regional Host/lead municipality. Agreements would need to be negotiated between the Regional Host and the other municipalities regarding how each would contribute to the maintenance and operation of the regional system.

Chapter 07
RECOMMENDATIONS, PRIORITIZATION, & FUNDING

The recommendations throughout this guidebook are revisited in this chapter to evaluate the cost, prioritization, and funding options each agency should factor into their considerations for each recommendation. Each of these phasing strategies have been considered with an eye on advancing the overall goals determined for this study. As with the previous chapters, the recommendations for Cary and Morrisville have been identified separately from recommendations made for Apex, Fuquay-Varina, and Holly Springs.

7.1 PHASING, PRIORITIZATION, AND COST OF RECOMMENDATIONS

Throughout the development of this guidebook, stakeholders have been evaluating the current state of their respective signal system operations and the potential of moving toward cohesive regional system integration. This guidebook is intended to evaluate the implications and viability of regional integration as have been described in the implementation plan as well as the operations and maintenance focused chapters. These phased recommendations are a result of the development of those chapters.

A series of goals were identified to specifically address how the region should mature within the dimensions of the Capability Maturity Model. These goals provide key benefits to the participating municipalities, which are also delineated below:

G1: Regional Traffic Signal System Integration

The integration of multiple municipalities into a regional traffic signal system will facilitate three primary benefits:

- **Improved Regional Mobility and Safety:** Drivers are unaware of jurisdictional boundaries as they pass from a signal controlled by one agency to a signal controlled by another agency. However, signals are often optimized based on individual agency preferences, performance measures, and re-timing intervals and can result in less optimal flow between varying jurisdictions. A regional system would enable integration of signals for a single holistic system among the jurisdictions involved, resulting in reduced travel time, reduced stops, improved travel time reliability and predictability, increased safety, and reduced emissions.
- **Shared Resources:** The municipalities will be able to pool key resources including staff expertise in varying disciplines, facilities within the region, tools and equipment, and monetary resources for enhanced buying/contracting effectiveness.
- **Reduced Operational Costs:** When compared with separate individual agency systems, a regional traffic signal system can result in overall cost savings for the included jurisdictions.

G2: Hardware/Software Standardization

- **Shared Resources:** The efficiencies that accompany joint operations and maintenance of signal system infrastructure can be enhanced by reducing the varying types of hardware and software systems that must be operated and maintained by the staff. This is a benefit that will be increased over time as varying projects and initiatives seek to standardize equipment within a regional system.
- **Interoperability and Partnering:** Standardization of hardware and software systems will create efficiencies not only within the region but also with agencies external to the proposed regional signal system. These could include Durham, Garner, Raleigh, and NCDOT arterial and freeway operations for enhanced signal timing, transit signal priority/bus rapid transit, and integrated corridor management.

G3: Defined Roles and Responsibilities

- **Shared Resources:** The municipalities will be able to pool key resources including staff expertise in varying disciplines.
- **More Extensive Expertise and Specialization:** Since staff will be pooled among the region, it will enable extensive specialization and development of expertise for the region—especially with emerging technologies. This encourages development of a culture of excellence and innovation.
- **Improved Regional Mobility and Safety:** Specialization and pooled resources will ultimately result in a higher signal system level of service. This will create holistic system improvements among the jurisdictions involved, resulting in reduced travel time, reduced stops, increased safety, and reduced emissions.

G4: System Resiliency

- **Increased Security and Protection of the Traveling Public:** Providing increased resiliency and security of the transportation network enables management of more highly secure and reliable transportation networks for the traveling public.
- **Improved Regional Mobility and Safety:** Improved resiliency will result in less system downtime for traffic signals and cameras, thus increasing overall signal system level of service. This will create holistic system improvements among the jurisdictions involved, resulting in reduced travel time, reduced stops, increased safety, and reduced emissions

G5: Program Sustainability and Expansion

- **Improved Regional Mobility and Safety:** The rollout of additional signal system technologies and innovative approaches will improve overall signal system level of service over time. This will create holistic system improvements among the jurisdictions involved, resulting in reduced travel time, reduced stops, increased safety, and reduced emissions.
- **Enhanced Internal Efficiency:** Implementation of automation and more effective monitoring systems will increase internal staff efficiency and capabilities over time. It will also increase traffic signal system uptime, improving reliability.

G6: Accountability through Performance Measures

- **Improved Regional Mobility and Safety:** Holding operations and maintenance staff accountable through the implementation of performance metrics will improve overall signal system level of service over time. This will create holistic system improvements among the jurisdictions involved, resulting in reduced travel time, reduced stops, increased safety, and reduced emissions.
- **Interoperability and Partnering:** Clear performance measures will enable each member of the regional partnership to ensure equitable distribution of operations and maintenance resources as well as equitable payment for services received. This will increase overall system performance, interoperability, and trust among partner agencies.

The following series of tables identify recommendations for near, mid, and long-term phased approaches to advancing toward a regional system. Each recommendation includes the assumptions used to make the recommendation, the cost considerations, potential funding source alignment, and maps back to the specific goals as identified above. It should be noted that all costs are estimated in current year (2022) dollars and are not financially constrained, as such the recommended phasing years are subject to funding availability. Potential funding sources are based on current available funding sources but should continue to be reevaluated through the life of this plan's implementation to seek other available funding opportunities.

NEAR-TERM CARY AND MORRISVILLE RECOMMENDATIONS

These recommendations have been identified as actions for the near-term, within the next three years, and apply to the Town of Morrisville and the Town of Cary. Each project brief identifies the actions recommended and projects are prioritized as the first actions to be taken for Cary and Morrisville.

1. Integrate additional Town of Morrisville traffic signals into the Town of Cary signal system network.

- **Assumptions:** Assumes 8 of the 14 Morrisville signals still maintained by NCDOT will be interconnected and upgraded to Cary standards with the NCDOT road widening projects. Assumes the remaining 6 existing signals do not have fiber connectivity and need to be upgraded to Town of Cary network hardware specifications and requirements when transitioning them to Town of Cary operations and maintenance.
- **Cost Considerations:** $650,000 (intersection upgrades, integration, and fiber construction)
- **Potential Funding Source Alignment**:
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s)**:
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G5: Program Sustainability and Expansion

2. Add Town of Cary operations and maintenance staff to support organic growth of the Cary signal infrastructure and integration of all signals in Morrisville.

- **Assumptions:** One additional operations staff member and one additional maintenance staff member are needed to manage existing and proposed traffic signals for a joint system.
- **Cost Considerations:** $215,000 annually. For more details, refer to anticipated position cost tables
- **Potential Funding Source Alignment:** Likely to be local funding with partial NCDOT funding through Schedule C and D apportionments. However, a portion of funding may be coverable over a short period of time by federal grants when coupled with related capital investments through:
  - Congestion Relief Program
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G3: Defined Roles and Responsibilities

- G5: Program Sustainability and Expansion
- G6: Accountability through Performance Measures

3. Dedicate traffic signal and maintenance/storage space in the new Town of Morrisville Public Works facility, which is currently under design.

- **Assumptions:** Assumes initial discussions have taken place to define the amount of space Cary is looking to utilize in the Morrisville Public Works Facility. Space should be adequate or expandable to accommodate future test cabinet and bench repair maintenance activities and new technology troubleshooting and burn-in.
- **Cost Considerations:** It is anticipated no separate costs are being defined for the building space or utilities.
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency

4. Conduct a regional communications infrastructure study.

- **Assumptions:** The study's scope of work can be very detailed to include:
  - Analysis of fiber-optic communications cable needs for new construction, upgrades, and replacement of aged fiber
  - Network hardware and software documentation
  - Analysis of network topology and resiliency
  - Security review
  - Integration among agencies and access to specific facilities
  - Analysis of fiber asset management tools
  - Phasing and cost analysis with return-on-investment analysis
- **Cost Considerations:** Anticipate study cost of $200,000 (Note: if completed with Apex/Fuquay-Varina/Holly Springs at the same time, anticipate study cost to be $350,000 for all 5 municipalities)
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - Congestion Relief Program (only when grouped as a larger project with other initiatives)
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
  - State and Local Cybersecurity Grant Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

5. Add cameras to Morrisville intersections based on operational needs.

- **Assumptions:** Assumes none of the existing 43 Morrisville signals have cameras to date, but that each intersection has existing fiber connectivity (or will have at time of camera install). Assumes cameras are to be mounted to existing poles. Assumes video management software exists.

- **Cost Considerations:** $350,000
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - May be included as part of a larger grant proposal related to:
        - Congestion Relief Program
        - Strengthening Mobility and Revolutionizing Transportation Grants Program
        - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G5: Program Sustainability and Expansion
    - G6: Accountability through Performance Measures

6. Update and execute agreements between Town of Cary and Town of Morrisville for the ongoing shared resources and management of signals including:

a. Collaboration between the two agencies to ensure network security.

b. Definition of roles and responsibilities, as they relate to the system, between varying members of the Town of Cary and Town of Morrisville agencies.

c. Development of performance requirements for availability and reliability for fiber infrastructure.

d. Development of performance requirements for traffic signal operations.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G2: Hardware/Software Standardization
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion
    - G6: Accountability through Performance Measures

The following recommendations have been identified as actions for the mid-term, within the next three to six years, and apply to the Town of Morrisville and the Town of Cary.

7. Establish redundant, path-diverse C2C connection between Cary and Morrisville facilities to enable Morrisville staff to view CCTV cameras and system operations.

- **Assumptions:** Assumes the Regional Communications Infrastructure Study would identify the needed path and/or fiber upgrade necessary to support the bandwidth needed for video and future technologies.
- **Cost Considerations:** This cost could vary based on building entrance requirements and length of new fiber to be constructed but would be estimated around $250,000–$400,000.
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - May be included as part of a larger grant proposal related to:
        - Congestion Relief Program
        - Strengthening Mobility and Revolutionizing Transportation Grants Program
        - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion
    - G6: Accountability through Performance Measures

8. Provide user access for Fire Departments, Police, and Emergency Departments based on operational need.

- **Assumptions:** Assumes the connectivity is in place from Recommendation #7. Some training and coordination may be needed but it is anticipated this will occur as part of normal coordination and operations between the agencies.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G3: Defined Roles and Responsibilities
    - G6: Accountability through Performance Measures

9. Establish traffic signal maintenance and storage space in new Town of Morrisville Public Works Facility once construction is completed.

- **Assumptions:** Assumes this item establishes the space defined in the Near-Term Recommendation #3.
- **Cost Considerations:** $75,000 for additional maintenance truck. It is anticipated no separate cost is required for the building space or utilities.

- **Potential Funding Source Alignment:** Local funding
- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency

10. Begin implementation of technologies used in Cary to the Morrisville signals where appropriate (i.e., TSP, EVP).

- **Assumptions:** Assumes continual upgrades to ensure the Town of Morrisville signals have the same capabilities and technologies deployed as the Town of Cary signals. Assumes signal and communication infrastructure is existing. Assumes only the specific device technologies to be added. Transit Signal Priority, Emergency Vehicle Preemption, and Connected Vehicle Capability to be added. Accessible Pedestrian Signals and Leading Pedestrian Intervals to be required for all future new signal implementation or signal upgrades by developers.
- **Cost Considerations:** $300,000
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Safe Streets and Roads for All Grant Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

11. Implement ATSPM at all traffic signals along key corridors in Cary and Morrisville.

- **Assumptions:** Assume 100 intersections in Cary and Morrisville.
- **Cost Considerations:** $300,000. Assumes in-house managed system for capital outlay. Could also be implemented as outsourced system with operational outlay.
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Safe Streets and Roads for All Grant Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

12. Evaluate potential ICM corridor along I-40, NC 54, Aviation Parkway, Airport Boulevard, I-540, NC 147, and Harrison Avenue.

- **Assumptions:** Assumes the design portion of ICM routes/plans, Dynamic Trailblazers, and Roadside Units included in this step.
- **Cost Considerations:** $300,000 (planning and design)
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G2: Hardware/Software Standardization
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

13. Establish communications connectivity to neighboring jurisdictions (Durham and Raleigh).

- **Assumptions:** Assumes existing fiber overlap points; assumes integration to the extent of system compatibility, otherwise specific data may be shared.
- **Cost Considerations:** $200,000
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - May be included as part of a larger grant proposal related to:
        - Congestion Relief Program
        - Strengthening Mobility and Revolutionizing Transportation Grants Program
        - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

14. Perform a transportation network-specific cybersecurity assessment.

- **Assumptions:** Assumes the IT departments from each agency will work together to self-perform a network security assessment; no outside facilitator or counsel necessary.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G4: System Resiliency

- G5: Program Sustainability and Expansion
- G6: Accountability through Performance Measures

LONG-TERM CARY AND MORRISVILLE RECOMMENDATIONS

The following recommendations have been identified as actions for the long-term, in the next six to 10 years, and apply to the Town of Morrisville and the Town of Cary.

15. Implement ICM technologies along I-40 parallel arterials and cross-connecting interchange arterials.

- **Assumptions:** Assumes funding for this phase would be procured under Recommendation #12.
- **Cost Considerations:** $500,000 (construction and integration)
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - Congestion Relief Program (only when grouped as a larger project with other initiatives)
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
  - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion

16. Build-out fiber connections to new or peripheral signals within Cary and Morrisville.

- **Assumptions:** Assumes existing signals are connected under Recommendation #1. This recommendation is for future signals that will be added or for interconnecting NCDOT signals on the periphery of the Town of Cary.
- **Cost Considerations:** Varies, but could use the below rules of thumb:
  - Assume $250,000 for new signal construction
  - Assume $25 per linear foot for of conduit/fiber construction
  - Assume 15% of construction cost for design fee
  - Assume 15% of construction cost for system/software integration
- **Potential Funding Source Alignment:**
  - Development requirements
  - Local funding
  - STIP funding
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G4: System Resiliency

- G3: Defined Roles and Responsibilities
- G5: Program Sustainability and Expansion

17. Implement ATSPM at all remaining traffic signals in Cary and Morrisville.

- **Assumptions:** Assume 140 intersections in Cary and Morrisville.
- **Cost Considerations:** $420,000. Assumes in-house managed system for capital outlay. Could also be implemented as outsourced system with operational outlay.
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - Congestion Relief Program (only when grouped as a larger project with other initiatives)
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
  - Safe Streets and Roads for All Grant Program
  - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion

18. Establish pilot program for testing of new technologies as they become available throughout the system.

- **Assumptions:** Assumes a manageable size pilot for each technology; balance staff capacity and capability for each pilot.
- **Cost Considerations:** Budget for $50,000–$100,000 annually for piloting technologies (or could consider a $200,000 pilot every 2-3 years).
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - Congestion Relief Program (only when grouped as a larger project with other initiatives)
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
  - Safe Streets and Roads for All Grant Program
  - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion

19. Consider Smart City connectivity and other advanced technologies when planning and investing in the communication networks.

- **Assumptions:** Assumes this has been accounted for within Recommendation #4. Keep in mind that technologies are likely to change prior to the Regional Communications Infrastructure Study being updated. This will tie closely with Recommendation #17.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

20. Add Town of Cary operations and maintenance staff to support organic growth of the Cary signal infrastructure and integration of additional signals in Morrisville (as needed).

- **Assumptions:** Assumes staff levels are adequate for existing system size. As the system grows, additional staff positions may be needed based on FHWA guidelines described in Chapter 5.
- **Cost Considerations:** Refer to average staffing cost information in the provided Excel tables.
- **Potential Funding Source Alignment:** Local funding
- **Supports Goal(s):**
    - G3: Defined Roles and Responsibilities
    - G5: Program Sustainability and Expansion

21. Provide connectivity to allow for electronic signal lab capabilities in new Town of Morrisville Public Works Facility.

- **Assumptions:** Assumes the physical connectivity is accounted for in Recommendation #7. This recommendation would include procurement of test cabinet and equipment for a signals lab.
- **Cost Considerations:** $50,000 for lab equipment
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - May be included as part of a larger grant proposal related to:
        - Congestion Relief Program
        - Strengthening Mobility and Revolutionizing Transportation Grants Program
        - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G3: Defined Roles and Responsibilities
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

The following recommendations are a result of the development of the Implementation Plan and Operations & Maintenance chapters. These recommendations have been identified as actions for the near-term, within the next three years, and apply to all the municipalities interested in the regional collaborative. They are prioritized as the first actions to be taken.

1. Each agency to evaluate potential participation in a regional system. Determine which agencies will be a part of the regional system.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary. Assumes Recommendations 1-3 occur sequentially, and consensus is reached quickly as agencies have discussed the alternatives throughout the development of this guidebook.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

2. Form a steering committee/oversight committee for the proposed regional system.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary. Assumes Recommendations 1-3 occur sequentially, and consensus is reached quickly as agencies have discussed the alternatives throughout the development of this guidebook.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

3. Determine who the Regional Host should be for the regional signal system.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary. Assumes Recommendations 1-3 occur sequentially, and consensus is reached quickly as agencies have discussed the alternatives throughout the development of this guidebook.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable

- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

4. Develop agreements between agencies for ongoing shared resources and management of signals including:

a. Definition of roles, responsibilities, data sharing requirements, and cost sharing responsibilities as they relate to the system.

b. Development of performance requirements for availability, reliability, and security of fiber infrastructure.

c. Development of performance requirements for traffic signal operations and maintenance.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; minimal outside facilitator or counsel assumed.
- **Cost Considerations**: $100,000 in coordination, performance measure development, and agreement development.
- **Potential Funding Source Alignment:**
  - Local funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

5. Begin requests for capital expenditures, new employee positions, and annual operating and maintenance expenses.

- **Assumptions:** Assumes consensus is reached for Recommendations 1-3.
- **Cost Considerations:** Refer to cost tables in the provided Excel file for budget planning based on agency commitment.
- **Potential Funding Source Alignment:** Local and NCDOT Schedule C & D
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization

- G3: Defined Roles and Responsibilities
- G5: Program Sustainability and Expansion

6. Construct the proposed Fuquay-Varina signal system.

- **Assumptions:** Assumes the construction of the existing NCDOT TIP project U-6022. Contractor training can be leveraged for both NCDOT and municipal staff.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Funding has already been allocated through NCDOT TIP U-6022.
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G5: Program Sustainability and Expansion

7. Conduct a regional communications infrastructure study.

- **Assumptions:** The study's scope of work can be very detailed following this project to include:
  - Analysis of fiber-optic communications cable needs for new construction, upgrades, and replacement of aged fiber
  - Network hardware and software documentation
  - Analysis of network topology and resiliency
  - Security review
  - Integration among agencies and access to specific facilities
  - Analysis of fiber asset management tools
  - Phasing and cost analysis with return-on-investment analysis
- **Cost Considerations:** $250,000 (Note: if completed with Cary/Morrisville at the same time, anticipate study cost to be $350,000 for all 5 municipalities)
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - Congestion Relief Program (only when grouped as a larger project with other initiatives)
  - Strengthening Mobility and Revolutionizing Transportation Grants Program
  - Congestion Mitigation and Air Quality Improvement Program
  - State and Local Cybersecurity Grant Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

The following recommendations have been identified as actions for the mid-term, within the next three to six years, and apply to all the municipalities interested in the regional collaborative.

8. Add cameras to individual intersections based on operational needs.

- **Assumptions:** Assumes a camera density of 25% of existing signals in Apex, Fuquay-Varina, and Holly Springs. Assumes the intersections have existing fiber connectivity and cameras are to be mounted to existing poles. Assumes video management software to be included in TMC budget.
- **Cost Considerations:** $350,000
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

9. Develop regional standards for signal system technology.

- **Assumptions:** Establish a regional program for ongoing evaluation and determination of regional hardware and software standards. This will include development of standard specifications, a qualified products list, and ongoing evaluation of new technologies. Anticipate this work to be complete by in-house staff.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization
  - G3: Defined Roles and Responsibilities
  - G5: Program Sustainability and Expansion

10. Design the Apex and Holly Springs portions of the regional system.

- **Assumptions:** Assumes system design like that of Fuquay-Varina Traffic Signal System.
- **Cost Considerations:** $300,000
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:

    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G5: Program Sustainability and Expansion

11. Design and construct the regional TMC and signal maintenance facilities.

- **Assumptions:** Assumes use of an existing facility and that space may be allocated for TMC operations and signal maintenance.
- **Cost Considerations:** Anticipate $1,200,000 in design, space retrofit, data center, video wall, and workstation costs. Also includes maintenance equipment (bucket trucks, pickup trucks, trailer).
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G3: Defined Roles and Responsibilities
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

12. Establish a C2C communications link between the regional TMC and the STOC.

- **Assumptions:** Assumes the Regional Communications Infrastructure Study in Recommendation #7 would identify the needed path and/or fiber upgrade necessary to support the bandwidth needed for video and future technologies.
- **Cost Considerations:** $400,000 (integration and additional software)
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program

- **Supports Goal(s):**
    - G1: Regional Traffic Signal System Integration
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

13. Elevate operations and maintenance of the regional system to increase LOS.

- **Assumptions:** Assumes this would require additional staff to meet the increased LOS as described in Chapter 6.
- **Cost Considerations:** Refer to current average position costs in the provided Excel file.
- **Potential Funding Source Alignment:** Local funding and NCDOT Schedule C & D Reimbursement
- **Supports Goal(s):**
    - G3: Defined Roles and Responsibilities
    - G5: Program Sustainability and Expansion
    - G6: Accountability through Performance Measures

14. Evaluate CV, EVP, and TSP technologies along key arterials within the regional system.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

15. Employ management of a network monitoring software to enable proactive and responsive network maintenance as a regional collaborative.

- **Assumptions:** Assumes purchase of commercial-off-the-shelf (COTS) offering.
- **Cost Considerations:** $150,000
- **Potential Funding Source Alignment:**
    - Local funding
    - May be included as part of a larger grant proposal related to:
        - Congestion Relief Program (only when grouped as a larger project with other initiatives)
        - Strengthening Mobility and Revolutionizing Transportation Grants Program
        - Congestion Mitigation and Air Quality Improvement Program
        - Advanced Transportation and Congestion Management Technologies Deployment Program
        - State and Local Cybersecurity Grant Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G5: Program Sustainability and Expansion

- G6: Accountability through Performance Measures

LONG-TERM REGIONAL COLLABORATIVE RECOMMENDATIONS

The following recommendations have been identified as actions for the long-term, in the next six to 10 years, and apply to all the applicable municipalities interested in the regional collaborative.

16. Construct the Apex and Holly Springs portions of the proposed regional system and integrate them into a regional system with the previously constructed Fuquay-Varina signal system.

- **Assumptions:** Construction of Apex and Holly Springs signal systems.
- **Cost Considerations:** $3,000,000
- **Potential Funding Source Alignment:**
  - STIP funding
  - Local funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G2: Hardware/Software Standardization
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion
  - G6: Accountability through Performance Measures

17. Light-up fiber-optic cable connections along the proposed regional communication ring to provide path-diverse, redundant, regional connectivity among municipalities.

- **Assumptions:** Assumes design and construction are completed as part of Recommendations #7 and #16.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion

18. Accommodate access for all agencies within the regional network such that each can view and monitor system performance.

- **Assumptions:** Assumes the connectivity is in place from Recommendation #17. Some training and coordination may be needed, but it is anticipated this will occur as part of normal coordination and operations between the agencies.

- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
    - G3: Defined Roles and Responsibilities
    - G6: Accountability through Performance Measures

19. Deploy TSP, EVP, and CV technologies throughout the system.

- **Assumptions:** Assumes upgrades to ensure signals have the same capabilities and technologies deployed as the neighboring town signals. Assumes signal and communication infrastructure is existing. Assumes only the specific device technologies to be added.
- **Cost Considerations:** $1,500,000
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Safe Streets and Roads for All Grant Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

20. Deploy ATSPM throughout the region.

- **Assumptions:** Assumes 175 signals.
- **Cost Considerations:** $525,000. Assumes in-house managed system for capital outlay. Could also be implemented as outsourced system with operational outlay.
- **Potential Funding Source Alignment:**
    - Local funding
    - STIP funding
    - Congestion Relief Program (only when grouped as a larger project with other initiatives)
    - Strengthening Mobility and Revolutionizing Transportation Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
    - Safe Streets and Roads for All Grant Program
    - Advanced Transportation and Congestion Management Technologies Deployment Program
- **Supports Goal(s):**
    - G2: Hardware/Software Standardization
    - G4: System Resiliency
    - G5: Program Sustainability and Expansion

21. Elevate operation and maintenance of the regional system from a level-of-service perspective to provide opportunities for enhanced traffic operations.

- **Assumptions:** Assumes decisions to be made mutually between Town staff; no outside facilitator or counsel necessary. Similar to Recommendation #13, just occurring again in the long-term.
- **Cost Considerations:** Not applicable
- **Potential Funding Source Alignment:** Not applicable
- **Supports Goal(s):**
  - G2: Hardware/Software Standardization
  - G4: System Resiliency

22. Achieve connectivity between the regional system and the nearby City of Raleigh and Town of Garner signal systems.

- **Assumptions:** Assumes existing fiber overlap points; assumes integration to the extent of system compatibility, otherwise specific data may be shared.
- **Cost Considerations:** $300,000
- **Potential Funding Source Alignment:**
  - Local funding
  - STIP funding
  - May be included as part of a larger grant proposal related to:
    - Congestion Relief Program
    - Strengthening Mobility and Revolutionizing Grants Program
    - Congestion Mitigation and Air Quality Improvement Program
- **Supports Goal(s):**
  - G1: Regional Traffic Signal System Integration
  - G4: System Resiliency
  - G5: Program Sustainability and Expansion

7.2 FUNDING OPPORTUNITIES

As mentioned previously in chapters 5&6 FHWA provides guidelines on staffing for operations and maintenance. these staffing levels are currently unsupported by NCDOT Schedule C&D reimbursement. Due to this lack of funding, it is anticipated that municipalities will be responsible for covering the gap for improved traffic signal system level of service. In addition to the need for increased O&M funding, many of the municipal signal system projects are being pushed back or eliminated from the STIP due to NCDOT budget priorities. Therefore, it is anticipated that grant funding will be critical to the success of a regional signal system.

At local and federal levels, there are a variety of grants available to support the betterment of our transportation infrastructure and systems. Many projects and applicants are vying for these dollars. This section aims to identify funding opportunities that align with the recommendations in this study. While some of these grants have existed for years and agencies may have pursued them for other projects; the information below may provide a new perspective on how each funding source may support these recommendations. There are also new funding opportunities as part of recent legislation that are becoming available for transportation and technology initiatives.

Table 7.1 captures a brief description from each of these grants' published information found at the included links.

Table 7.1: Funding Opportunities

Section Title	Potential Applicants	Description
Safe Streets and Roads for All Grant Program Click Here for Grant Overview	Metropolitan planning organizations; local governments; tribal governments	Establishes a grant program to develop and carry out comprehensive safety plans to prevent death and injury on roads and streets, commonly known as "Vision Zero" or "Toward Zero Deaths" initiatives.
Congestion Relief Program Click Here for Grant Overview	State; local governments; metropolitan planning organizations in large, urbanized areas (more than 1 million people)	Establishes competitive grants to advance innovative, integrated, and multimodal solutions to congestion relief in the most congested metropolitan areas of the United States. Grant awards shall be not less than $10 million. When selecting grants, the DOT Secretary shall give priority to eligible projects located in urbanized areas that are experiencing high degrees of recurrent congestion. The federal cost-share shall not exceed 80 percent of the total cost of a project.
Strengthening Mobility and Revolutionizing Transportation Grants Program Click Here for Grant Overview	Local governments; metropolitan planning organizations	Competitive grant program to conduct demonstration projects focused on advanced smart city or community technologies and systems in a variety of communities to improve transportation efficiency and safety.
State & Local Cybersecurity Grant Program Click Here for Grant Overview	State; local governments; tribes	Establishes a grant program at the Department of Homeland Security (DHS) to address cybersecurity risks and threats to information systems. Potential uses: implement a cybersecurity plan to enhance cybersecurity and conduct activities that address imminent cybersecurity threats.

Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program **Click Here for Grant Overview**	State or local government; transit agency; metropolitan planning organization (MPO) representing a population of more than 200,000; multijurisdictional group made up of the above eligible applicants with a signed agreement to implement the initiative across jurisdictional boundaries; consortium of research or academic institutions	Established to make competitive grants for the development of model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. Funds may be used to deploy advanced transportation and congestion management technologies, including the following: • Advanced traveler information systems. • Advanced transportation management technologies. • Infrastructure maintenance, monitoring, and condition assessment. • Advanced public transportation systems. • Transportation system performance data collection, analysis, and dissemination systems. • Advanced safety systems, including vehicle-to-vehicle and vehicle-to-infrastructure communications. • Technologies associated with autonomous vehicles and other collision avoidance technologies, including systems using cellular technology. • Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems. • Electronic pricing and payment systems. • Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals.
Congestion Mitigation and Air Quality Improvement (CMAQ) Program **Click Here for Grant Overview**	State governments	Intended to support state and local governments with transportation projects and programs to help meet the requirements of the Clean Air Act. Funding is available to transportation projects that reduce congestion and improve air quality for areas that do not meet the National Ambient Air Quality Standards for ozone, carbon monoxide, or particulate matter (nonattainment areas) and for former nonattainment areas that are now in compliance (maintenance areas).
NCDOT State Transportation Improvement Program (STIP) **Click Here for Grant Overview**	Local governments; metropolitan planning organizations	The N.C. Department of Transportation's transportation plan – called the State Transportation Improvement Program (STIP) – identifies the construction funding and schedule for projects over a 10-year period. NCDOT updates the STIP approximately every two years. A strategic project prioritization process is conducted using transportation data, input from local government partners, and the public to generate criteria-based methodologies to support how local points are allocated for scores and rankings. The STIP projects are funded from various FTA, FHWA, and state funds and many require state and/or local matches.
Highway Safety Improvement Program (HSIP) **Click Here for Grant Overview**	State governments	The Highway Safety Improvement Program (HSIP) is a core Federal-aid program with the purpose to achieve a significant reduction in traffic fatalities and serious injuries on all public roads. The HSIP requires a data-driven, strategic approach to improving highway safety on all public roads with a focus on performance.
General or Local Funding	Local, State, or private	It is anticipated that many projects will be funded at the local and state level that have impacts to the regional signals system. These projects should consider this guidebook for implementation or expansion of the signal system.

7.3 PROGRAM COST OVERVIEW

Throughout the development of the Integration Guidebook, the team discussed a number of factors to consider when evaluating system costs. Based on these discussions, the guidebook has focused on the integration of the Cary and Morrisville traffic signals as well as the potential to form a larger regional system of like-minded agencies with similar expectations. The following tables provide an overview of both capital and operational costs for the entire program.

The capital costs are categorized by groups of agencies in concurrence with the implementation plan and the above prioritization plan. Cary and Morrisville are grouped together, and Apex, Fuquay-Varina, and Holly Springs are grouped together for capital costs.

Table 7.2: Capital Cost

Capital Costs		
Cary and Morrisville Integrated System	Near-term	$ 1,200,000
	Mid-term	$ 1,575,000
	Long-term	$ 1,070,000
		$ 3,845,000
Apex, Fuquay-Varina, and Holly Springs Integrated System	Near-term	$ 350,000
	Mid-term	$ 2,400,000
	Long-term	$ 5,325,000
		$ 8,075,000

Once the capital outlay has been made and the traffic signal system is in place, there are recurring operational and maintenance costs to account for. The operational costs provided here are developed based on staffing needs, annual software, hardware, and network maintenance costs. Table 7.3 includes two sections; the first section lays out the anticipated costs for different regional scenarios, and the second section lays out the anticipated costs for each agency to operate and maintain individual systems. The regional scenarios evaluated for consideration are:

- **Cary and Morrisville Integrated System** (assumes staffing and maintenance levels necessary to maintain LOS A)
- **Apex, Fuquay-Varina, and Holly Springs Integrated System** (assumes staffing and maintenance levels necessary to maintain LOS A)
- **Apex, Fuquay-Varina, and Holly Springs Integrated System** (assumes staffing and maintenance levels necessary to maintain LOS C)
- **Apex, Cary, Fuquay-Varina, Holly Springs, and Morrisville Integrated System** (assumes staffing and maintenance levels necessary to maintain LOS A)

These O&M costs are built based on the current system size for each scenario. It is understood that the Town of Cary already has an established program and staff, and Morrisville and Holly Springs have current O&M agreements in place for some signals. However, to evaluate the systems from the perspective of program budgeting, the anticipated costs are built for the needs of each system regardless of the elements currently in place. This provides a more complete view of each program's needs. The cost-effectiveness of these scenarios will be realized through pooled resources and infrastructure for operations and maintenance of the system.

Table 7.3: Annual Operations and Maintenance Costs

	Annual Operations and Maintenance Costs											
		No. of Signals	No. of CCTVs	Ops FTE	Ops Staffing Cost	Maint. FTE	Maint. Staffing Cost	**Total Annual Staffing Cost**	Software/ Hardware /Network Costs	Annual Fiber Maintenance Costs	Annual Vehicle Maintenance Costs	**Total Annual O&M Cost**
Regional System Scenarios	**Cary and Morrisville**	*238*	*166*	3.5	$ 464,277	10.0	$ 959,250	**$ 1,423,527**	$357,000	$ 25,000	$ 50,000	**$ 1,855,527**
	Apex, Fuquay-Varina, and Holly Springs (LOS A)	*174*	*9*	2.5	$ 333,819	6.5	$ 636,942	**$ 970,761**	$261,000	$ 45,000	$ 50,000	**$ 1,326,761**
	Apex, Fuquay-Varina, and Holly Springs (LOS C)	*174*	*9*	2.0	$ 268,590	4.5	$ 446,627	**$ 715,217**	$261,000	$ 45,000	$ 40,000	**$ 1,061,217**
	Apex, Cary, Fuquay-Varina, Holly Springs, and Morrisville	*412*	*175*	5.5	$ 725,193	16.5	$1,567,031	**$ 2,292,224**	$618,000	$ 60,000	$ 100,000	**$ 3,070,224**
Individual System Scenarios	**Apex (LOS A)**	*65*	*5*	1.0	$ 138,132	2.5	$ 253,242	**$ 391,374**	$97,500	$ 15,000	$ 20,000	**$ 523,874**
	Cary (LOS A)	*195*	*166*	3.0	$ 399,048	8.5	$ 837,233	**$ 1,236,281**	$292,500	$ 45,000	$ 50,000	**$ 1,623,781**
	Fuquay-Varina (LOS A)	*52*	*3*	1.0	$ 138,132	2.0	$ 212,570	**$ 350,702**	$78,000	$ 15,000	$ 20,000	**$ 463,702**
	Holly Springs (LOS A)	*57*	*1*	1.0	$ 138,132	2.0	$ 212,570	**$ 350,702**	$85,500	$ 15,000	$ 20,000	**$ 471,202**
	Morrisville (LOS A)	*43*	*0*	1.0	$ 138,132	1.5	$ 142,736	**$ 280,868**	$64,500	$ 15,000	$ 20,000	**$ 380,368**

While **Tables 7.2 and 7.3** provide a picture of how both the capital and O&M costs stack up, it is also valuable to review the variation in cost depending on how integrated a regional system is structured to be. **Table 7.4** summarizes the program costs and efficiencies gained through integrated systems and combined resources.

Table 7.4: Program Cost Overview

Alternative	Total Annual O&M Cost	Annual O&M Cost Per Signal	% Increase in O&M Costs	Implementation Cost	% Increase in Implementation Cost	Regional 10-Year Cost
2 Regional Systems	$3,182,288	$5,730	5%	$11,920,000	12%	$43,742,880
1 Regional System	$3,070,224	$5,450	0%	$10,620,000	0%	$41,322,238
5 Separate Systems	$3,462,927	$6,410	18%	$16,500,000	55%	$51,129,274

Chapter 08
REGIONAL ARCHITECTURE COMPLIANCE

8.1 RELATIONSHIP TO THE REGIONAL ITS ARCHITECTURE

The systems engineering process, as well as regulations on federally funded ITS projects, stipulate that similar projects within a region should align with any associated regional ITS architecture. For the Western Wake area, the Triangle Regional ITS Architecture encompasses all communities within the Triangle region as part of this study. The Triangle Regional ITS Architecture was updated in June 2020, converting the original 2010 version to the current version (at that time) of the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT). The Triangle Regional ITS Architecture includes all components that conform to the Federal Highway Administration (FHWA) regulations 23 CFR Part 940 for ITS Architecture and Standards.

8.2 ARCHITECTURE COMPLIANCE

The Western Wake Traffic System Integration Study recommendations should align with the Triangle Regional ITS Architecture per the FHWA's systems engineering process. The regional ITS architecture is comprised of service packages that capture the existing and planned interconnects and relationships needed to achieve the regional vision for ITS and operations.

Project Architectures

From the ***Regional ITS Architecture Guide***, November 5, 2020 (https://www.arc-it.net/documents/raguide/raguide.pdf), "*…project ITS architecture is to illustrate and document…a representation of the project that can be used to support systems engineering outputs for the project…"* Essentially, project architectures provide a framework of the scope of a single ITS project as it relates within a region and the interfaces of all regional ITS projects.

The Triangle Regional ITS Architecture included 21 ITS project architectures. This simply means the regional stakeholders identified at least 21 different projects the region would like to implement to ensure the vision of the Triangle region. For the Western Wake Signal System Study, the "Consolidate Municipal Signal Systems Management" project architecture best fits into the regional vision and this project.

The service package associated with this project architecture was the TM07 – Regional Traffic Management. In addition to this project architecture, there are other components that should be considered for compliance with the regional ITS architecture.

Operational Components

The Western Wake Signal System Study is looking at three distinctive options for integrating smaller signal systems into more regionally managed signal systems. The study is identifying all components of what would be included for the integration and the steps on how to integrate the systems efficiently.

The options include:

1. Integrating Morrisville signals into the Cary signal system
2. Integrating Apex, Fuquay-Varina, and Holly Springs signals into a regional system
3. Integrating Apex, Cary, Fuquay-Varina, Holly Springs, and Morrisville signals into a regional system

Although this study details the hardware, software, maintenance, funding, etc. of what would need to occur for the integration, the regional ITS architecture would be agnostic to most of these details.

To ensure compliance with the Triangle Regional ITS Architecture, the service packages are compared to the operational components impacted by the integration of the signal systems and for sharing video for regional coordination.

Those operational components include:

- Traffic signals timing and coordination
- Regional coordination
- Emergency vehicle preemption (EVP)
- Transit signal priority (TSP)
- Integrated Corridor Management (ICM)
- Connected vehicle (CV) infrastructure at signalized intersections
- Automated traffic signal performance measures (ATSPM)
- Closed-circuit television (CCTV) cameras

Even though the compliance is based on operational components, the actual "how to operate" the signal systems would be part of the systems engineering process, not the compliance with the Triangle Regional ITS Architecture.

ITS Service Packages

There are many ITS service packages under the current ARC-IT. Currently there are approximately 150 different service packages that represent varying methods of deploying ITS to meet the needs of a region, state, or community.

The two most applicable to this study include TM07 – Regional Traffic Management and TM03 – Traffic Signal Control. These service packages together allow for the coordination of traffic signal systems using real-time communications.

Table 8.1 includes a list of stakeholders and their associated inventory from the 2020 Triangle Regional ITS Architecture. **Table 8.2** includes the project-specific service packages, operational component, and their conformance from the 2020 Triangle Regional ITS Architecture and Triangle Region ITS Strategic Deployment Plan Update. Those denoted with a check (✓) are in compliance; those with a (✓*) are in compliance but will need to be updated once the project has been implemented; and those with an (x) are not in compliance. If the service package is non-compliant, refer to **Table 8.3** for which service packages are needed.

Table 8.1 Triangle Regional ITS Architecture Stakeholders & Inventory

Stakeholders (from RAD-IT)	Stakeholder Inventory (RAD-IT)	Apply(s) to
Local Traffic Management Departments	Local Traffic Operations Centers	• Town of Morrisville • Town of Apex • Town of Holly Springs • Town of Fuquay-Varina
	Local Traffic Signals	
	Local ITS Field Equipment*	
Cary	Cary CV Field Devices	Town of Cary
	Cary CCTV Cameras	
	Cary TOC	
	Cary Traffic Signals	
NC Department of Transportation	NCDOT CV Roadside Equipment	NCDOT
	NCDOT CCTV Cameras	
	NCDOT STOC	
	NCDOT Traffic Signals	
	NCDOT Triangle RTMC	
	Triangle Region – Traffic Data Warehouse	

**Local ITS Field Equipment includes CCTV cameras as part of the equipment listing.*

Table 8.2 Conformance of Project-Specific Service Packages

Operational Components	Associated Service Packages	Conformance
Town of Cary signal control of local signals	TM07 – Regional Traffic Management – NCDOT RTMC (3 of 3) Cary/Chapel Hill	✓
	TM03 – Traffic Signal Control – Local	✓*
NCDOT signal control of local signals	TM07 – Regional Traffic Management – NCDOT RTMC (1 of 3)	✓
	TM03 – Traffic Signal Control – Local	✓*
EVP (Cary/Local)	PS03 – Emergency Vehicle Preemption –- Local	✓*
EVP (NCDOT/Local)	PS03 – Emergency Vehicle Preemption – Local	✓*
TSP (Cary/Local)	PT09 – Transit Signal Priority – GoTriangle/Cary	*x*
TSP (Cary/Local)	PT09 – Transit Signal Priority – GoCary	*x*
TSP (NCDOT/Local)	PT09 – Transit Signal Priority – GoTriangle/Other Local Traffic Systems	✓*
CV at signalized intersections (Cary/Local)	*TM04 – n/a*	*x*
CV at signalized intersections (NCDOT/Local)	TM04 – Connected Vehicle Traffic Signal Systems	✓*
ATSPM collected and provided to Cary from the local signals (Cary/Local)	TM03 – Traffic Signal Control – Local	✓*
	TM02 – Vehicle-Based Traffic Surveillance - Cary	✓*
	DM01 – ITS Data Warehouse – Triangle Regional Traffic Data Warehouse	✓*
ATSPM collected and provided to NCDOT from the local signals (NCDOT/Local)	TM03 – Traffic Signal Control – Local	✓*
	TM02 – Crowd-Sourced and Vehicle-Based Traffic Surveillance – NCDOT	✓*
	DM01 – ITS Data Warehouse – Triangle Regional Traffic Data Warehouse	✓*
Town of Cary control of local CCTV cameras	TM07 – Regional Traffic Management – NCDOT RTMC (3 of 3) Cary/Chapel Hill	✓
	TM01 – Infrastructure Based Traffic Surveillance – Local TOCs	✓*
NCDOT control of local CCTV cameras	TM07 – Regional Traffic Management – NCDOT RTMC (1 of 3)	✓
	TM01 – Infrastructure Based Traffic Surveillance – Local TOCs	✓*

**correspond to service packages that would need to update their status within the regional ITS architecture once the project has been implemented.*

Table 8.3 Project-Specific Service Packages to be Added

Operational Components	ARC-IT v9 Service Package to be Added
TSP (Cary/Local)	Add Local Traffic Signals and Local TOC to PT09 – Transit Signal Priority – GoTriangle/Cary
CV at signalized intersections (Cary/Local)	Add TM04 – Connected Vehicle Traffic Signals System – Cary/ Local Traffic Systems

Appendix A

APPENDIX A: PEER REVIEWS

AGENCIES SELECTED

In an effort to see how other regional partnerships across the country approach traffic signal integration, several similar agencies were interviewed to assess their existing conditions and future implementation and coordination plans. The agencies were selected based on current systems and integrations and those that showed similar aspects to Western Wake County.

The City of Memphis TN, City of Frisco TX, Sacramento County CA, and Maricopa County AZ currently have signal systems that share resources to operate and maintain signals with neighboring partners. Each of these agencies collaborate and work in different ways to provide a variety of experiences and lessons learned to support Western Wake County in the evaluation of system integration.

CITY OF MEMPHIS

The City of Memphis (TN) has a signal system that was first implemented in the 1960's. City staff operate and maintain their infrastructure but due to staff capacity the City has also been maintaining signals for surrounding municipalities in the area.

The City of Memphis, and some of their neighbors have fiber-optic cable connections for data sharing, but each organization operates their own system. The City of Memphis provides emergency (or "as needed") maintenance as a work order that gets charged to other municipalities on a labor and materials basis. These maintenance agreements were not formalized until recently, when the City of Memphis has been developing MOUs to record and delineate the work they can perform.

Current maintenance agreements do not have a required level of service and only provide services to maintain and restore operations rather than providing services such as decorating cabinets to match others or providing preventive maintenance. Their work also prioritizes the City of Memphis signals maintenance over other municipalities when work needs to be performed at several locations at a time.

Given the amount of work and limited staff, the City of Memphis has stopped expanding operations even though other neighbors have requested assistance.

CITY OF FRISCO

The City of Frisco (TX) is located in the Dallas Forth Worth metropolitan area. Their signal system and operations are relatively new as they have seen a growth from 11 signals to 165 signals in the past 20 years. Agreements in Texas also specify that any city with more than 50,000 residents must take over responsibility from TXDOT to maintain the signals and roads within their jurisdiction, so the City of Frisco has taken a leading role in the area as neighboring cities grow.

The City of Frisco is neighbor to Little Elm, McKinney, Plano and Prosper, Texas. The City of Frisco has taken on some role to maintain these neighboring signals systems. Payment for this maintenance is made to the City of Frisco on an annual service fee basis for each intersection maintained. For Little Elm and Prosper, the City of Frisco maintains signals in a shared corridor, meanwhile for Plano and McKinney the City of Frisco also shares video management system and works together for signal coordination and retiming.

Given the fast growth, the City of Frisco's fiber backbone is less than 5 years old, and they mainly rely on a wireless infrastructure system for traffic signal communications. There are also some fiber optic cables in the area used for Center-to-Center communications with other regional municipalities and utilities.

The City of Frisco currently utilizes standard agreements created by TXDOT to maintain neighboring systems. The payment structure is $7,500 per intersection per year for maintenance. One condition of the agreements is that each city must upgrade or swap-out their signal equipment to match the City of Frisco standards before the City of Frisco will perform maintenance. Agreements also provide opportunities for the City of Frisco to design and construct new signals on a labor and materials basis. Alternately, the agreements allow for the municipalities to utilize consultants for design services. The current agreements do not stipulate a level of service requirement, but the internal policy for the City of Frisco is to respond to any emergency within 45 minutes of it being reported.

Other agencies have approached the City of Frisco for maintenance support on their systems, but they have stopped expanding operations due to limited staff.

SACRAMENTO COUNTY

Sacramento County (CA) currently has over 90 signals that have always been run by the County Signal Department. In the past, the County had ownership of all signals in the County, outside the City of Sacramento, but as new municipalities have incorporated within the County the new municipalities have assumed ownership of their signals. Due to staff availability the County operates and maintains signals for the cities of Rancho Cordova, Citrus Heights and Elk Grove. Each city has their own server and system that the County can access. The County has the ability to control any signal in the area and monitor CCTV cameras. For the maintenance and operations agreement, the County uses an RFP system to propose their services to surrounding cities. These contracts provide service level requirements for response times. There are also requirements for signal timing travel-time-runs to evaluate efficiency of corridors as well as requirements for timely review of any signal/timing plans.

With these agreements, the County charges each city on a labor and materials basis to maintain any signal system. The County will also operate the system as well to ensure efficient operations. The County charges for operations by assigning a portion of their total signal operations budget based on the percent of signals belonging to each City.

All municipalities are also involved with the regional efforts of the Sacramento Area Council of Governments (SACOG) that provide coordination opportunities as well as regional planning. One of the main projects for SACOG has been to develop a server-to-server system connection between the cities and the County and create a unified network (STARNET) to connect all the different TMCs in the area with fiber to facilitate real-time data sharing.

MARICOPA COUNTY

Maricopa Country (AZ) is located in the Phoenix Metro area and operates and maintains over 170 signals that also have ATSPM capabilities. The County is part of the long-standing regional coalition of agencies named "AZTech" that includes partnerships between AZDOT, FHWA, 10+ municipalities, universities, and public safety departments.

In the area, partnerships between municipalities have worked to deliver ICM and communication projects for regionally important corridors. Currently, they are working on upgrading and deploying ATSPM and an adaptive system for Bell Road. This road requires collaboration from 7 different agencies. Given the AZtech partnership, each municipality works together for the end goal, but each of them can also select vendors and systems to meet their needs. It is required that all data be shared and stored in a regionally created, common archive system.

This data archive system also provides access to all police and fire departments to share information that might help all other agencies. With this system, there are currently four (4) different signal system vendors, but all agencies can access data from all and use it accordingly.

As part of AZtech, each municipality maintains their own system, but smaller agencies can request help from larger agencies. The MPO in the area also created an initiative to have maintenance agreements in place such that as any power outages occur, municipalities have contracts in place for resources needed to resolve any disruptions quickly.

PEER INTERVIEW TAKEAWAYS

Each of the agencies selected for peer interviews provided valuable feedback on their experiences and recommendations for the evaluation of system integration in Western Wake County. Some of the main takeaways they wanted to highlight include:

- To always be upfront with expectations for providing operations and maintenance to others. Having agreements in writing helps to delineate resources and expectations for all agencies involved.
- To not overcommit your resources by agreeing to help neighboring agencies.
- To start small with regional projects and build upon successes and make sure that data can be shared between all agencies.
- To acknowledge that one big regional signal system may not always be the best solution when looking at how to facilitate traffic operations across municipalities.
- Continuous partnership between agencies and regular meetings have shown great results.

Appendix B

APPENDIX B: SAMPLE MOU LANGUAGE

APPENDIX B.1: ROADMAP FOR REGIONAL AGREEMENTS

A roadmap for developing and executing regional agreements will be an important key to success for the Implementation plan approach to have a regional host to maintain and operate a regional signal system. With the integration of signals, cameras, software, and different hardware, it will be necessary for all agencies in the region to develop agreements in order to have a true regional system that can share data, share responsibilities and increase the current level of service for signals.

For the purposes of this discussion, “memorandum of understanding” or MOU may be used as a generic term for an agreement between two or more agencies. The final legal form of the agreement may end up being an Inter-Local Agreement, Service Level Agreement, or any other form based on the requirements of the agencies involved.

Regional agreements should consider:

- Explicitly stating all services provided as well as costs for maintenance, operations, and possible additional services for future signals to be designed.
- Determining if signals will be incorporated to an ATMS systems or if they will be working on a standalone system (this will be required for the short-term integrations while a regional network is deployed)
- Renewing agreements on a regularly scheduled basis. It is recommended to have longer term (5 to 10 years) agreements and not yearly agreements so agencies can understand the budgetary implications and plan accordingly.
- Crafting agreements that allow all agencies to maintain and operate signals for better level of service.
- Including performance measures in the services and keep records for all parties responsible in the agreement.
- If not using the same ATMS or software, including data sharing responsibilities for both parties with prioritized permissions to access/view/operate the.
- Responding to emergency calls based on traffic/safety importance of corridors, not based on agency owner.
- Sharing all system data between agencies (e.g. crash, delay, camera views, signal timing plans)..
- Sharing access to all real-time monitoring systems.
- Including the NCDOT maintenance agreement checklist that addresses signal operations and maintenance with expected recurring timeframes between revisions/maintenance checks.
- Specifications and standards for any new construction shall be identified as well to standardize systems as required by the host agency.

In addition, funding levels should support a regional host that maintains/operates all signals in the region. If funding includes reimbursement by NCDOT through Schedule C and D agreements, MOUs should take into consideration the requirements of NCDOT to insure reimbursement.

In order to reach a successful agreement, the following sections are recommended for all agreements:

Table Appendix B.1: Proposed Agreement Sections

Section	Description
General Scope	Summary of the agreement in place with official names of all entities and a high-level description of the services provided, reimbursement terms
General Provisions	Any terms related to following state or local policies and consequences of not complying to them
Scope of Project	Detailed description of the agreement including terms related to maintenance, operations, access, data sharing and software permits for any agencies
Timeframe	Recommend renewing every three years with options to revisit annually. If perennial multi-year agreements are used, add possible renewal periods
Responsibilities	Responsibilities for all agencies need to be outlined including payment responsibilities, terms of payments, data sharing responsibilities for operations, staff provided, administration activities, priority on emergencies and all items related to the operation/maintenance of the system. Add flow charts to detail communication methods for emergency calls and operations/maintenance. Additional support to the hosting agency should also be considered (such as IT staff).
Reimbursement	Detailed description of reimbursement terms for payment frequency including detailed descriptions (hardware/software if needed, labor, materials, etc.).
Records and Reports	Both agencies should maintain records on all maintenance and operations performed making performance measures readily available for accountability.
Maintenance and Operations Checklists	Checklists for expected maintenance items, operations and data sharing responsibilities, and frequency of services provided.

In addition to a regional signal system, this Guidebook also considers potential arrangements where one agency provides operational and maintenance services for another agency's traffic signals. The following is a sample agreement for such an arrangement. It has been pre-populated with information that could be used for agreements between the local agencies as well as for reimbursement agreements with NCDOT. The intent is to provide agencies a thorough and streamlined document, saving time and providing fair service for all parties. Document your agreement and measure work performed and services provided.

INTERLOCAL SERVICE AND COOPERATION AGREEMENT BETWEEN
“Municipality Requesting Agreement” AND “Host of the maintenance and operations”
OPERATIONS, MAINTENANCE, AND INTEGRATION OF DESIGNATED TRAFFIC SIGNALS

This INTERLOCAL AGREEMENT (“Agreement”) is entered into to be effective on the date that the last approving Party executes the Agreement, by and between “Municipality Requesting Agreement”, and “Host of the maintenance and operations”. Both agencies are sometimes referred to collectively as the “Parties” or individually as a “Party.”

W I T N E S S E T H:

WHEREAS the “Host of the maintenance and operations” has the requisite personnel to operate and maintain traffic signals; and

WHEREAS “Municipality Requesting Agreement” has determined that it will be more effective and efficient for “Host of the maintenance and operations” to operate and maintain the designated signalized intersections as listed on the Appendix I, attached hereto and incorporated herein by reference for all purposes; and

WHEREAS “Host of the maintenance and operations”, pursuant to the terms and conditions set forth in this Agreement, agrees to maintain and operate the designated signalized intersections with “Municipality Requesting Agreement” reimbursing “Host of the maintenance and operations” for all maintenance and operations costs as more fully described in the Appendices, attached hereto and incorporated herein by reference for all purposes; and

WHEREAS “Municipality Requesting Agreement” and “Host of the maintenance and operations” have adopted a resolution or ordinance by their respective governing bodies that authorize “Municipality Requesting Agreement” and “Host of the maintenance and operations” to enter into this Agreement, which are all attached hereto as Appendices and incorporated herein by reference for all purposes; and

WHEREAS, both agencies have a mutual interest in the efficient and effective operation of traffic signals within the Region; and

WHEREAS the agencies recognize that each party to this Agreement has an obligation and responsibility to provide for the safe, orderly, and efficient flow of traffic on their respective street systems; and

WHEREAS the “Municipality Requesting Agreement” finds that it is in the best public interest to operate traffic signals and maintain them regularly at certain intersections that are within the municipality; and

WHEREAS the “Municipality Requesting Agreement” finds it desirable and advantageous to reimburse the “Host of the maintenance and operations” for costs incurred when the host manages.

NOW, THEREFORE, this Agreement is made and entered into by “Municipality Requesting Agreement” and “Host of the maintenance and operations”, upon and for the mutual consideration hereinafter stated, which Parties hereby agree and understand as follows:

1. GENERAL PROVISIONS

COMPLIANCE WITH STATE/FEDERAL POLICY

The "Host of the maintenance and operations" and/or its agent, including all contractors, subcontractors, or sub-recipients, shall comply with all applicable Federal and State policies and procedures, stated both in this Agreement and in the State's guidelines and procedures.

FAILURE TO COMPLY - CONSEQUENCES

Failure on the part of the "Host of the maintenance and operations" to comply with any of the provisions of this Agreement will be grounds for "Municipality Requesting Agreement" to terminate participation in the costs of the Project and, if applicable, seek repayment of any reimbursed funds.

2. SCOPE OF THE PROJECT

The Municipality shall operate the traffic signals as defined in the Appendices and as indicated hereinafter:

A. The operation of intersections on the State Highway System and Municipal Signals, both at the hardware and software levels, will be subject to the approval of NCDOT, "Municipality Requesting Agreement" and "Host of the maintenance and operations" and will reflect the needs of traffic on both the State Highway System and the Municipal System.

B. The "Host of the maintenance and operations" agrees to an annual audit of the performance of intersection equipment and systems. The audit is to be performed by NCDOT, the "Municipality Requesting Agreement" and the "Host of the maintenance and operations" or any designated individuals (such as consultants) designated by any of the entities. Payment for these audit services will need to be considered during the negotiations and specified in the cost section.

C. The "Host of the maintenance and operations" shall not install any traffic control devices, nor make any traffic signal phasing changes, on any State Highway System street without the prior approval of the "Municipality Requesting Agreement", pursuant to NCGS §20-169.

D. The "Host of the maintenance and operations" shall operate the traffic signals in accordance with North Carolina General Statutes, the Department's current policies and guidelines as included in the Appendices, and all local codes and ordinances. If, in the opinion of the "Municipality Requesting Agreement", The "Host of the maintenance and operations" does not operate the traffic signals in accordance with the specified criteria, NCDOT and or the "Municipality Requesting Agreement" shall have the right to cancel this Agreement. Synchronization efforts shall also be coordinated between the agencies to communicate and agree on the most efficient functionality of the signalized corridor.

E. NCDOT shall review and concur with any contract entered into by The "Host of the maintenance and operations" for the operation of any traffic signal(s).

F. The "Municipality Requesting Agreement" shall comply to all standards and new construction specifications based on the requirements from the **"Host of the maintenance and operations"** If the "Host of the maintenance and operations" fails to comply with these requirements, the "Municipality Requesting Agreement" will withhold funding until these requirements are met.

G. Any additional traffic signals not listed on this agreement that wants to be added shall require a written request from the "Municipality Requesting Agreement". Such request shall be made in a form of a revised Exhibit-3 and shall be reviewed and accepted by the "Host of the maintenance and operations". Any new signals shall also include signal plans in accordance with all requirements from NCDOT that will need to be accepted by the "Host of the maintenance and operations". Any revisions shall be added to the contract and approved by all parties.

3. TIME FRAME

This agreement shall be for the current calendar year, beginning XXXXX and ending XXXXX. At the end of the fiscal year, the provision of services and quality of results may be reviewed by the "Municipality Requesting Agreement", "Municipality Requesting Agreement" and the "Host of the maintenance and operations". The Agreement may be extended for additional fiscal years, contingent upon the increase of NCDOT maintenance funds by the General Assembly and the "Municipality Requesting Agreement" funding. Extensions may be made in one (1) year increments, incorporating any mutually agreed upon adjustments, with the end of the final fiscal year of service being XXXXX. On behalf of The "Host of the maintenance and operations", extensions may be authorized and executed by the Town/City Manager and/or Mayor without further resolution of the Town/City Council. The agreement may be terminated by either party upon a thirty (30) day written notice.

4. RESPONSIBILITIES

"Municipality Requesting Agreement" Responsibilities:

A. "Municipality Requesting Agreement" shall pay the "Host of the maintenance and operations" for maintenance, operation and labor costs for the services and functions the "Host of the maintenance and operations" incurs pursuant to this Agreement as provided in this agreement.

B. "Municipality Requesting Agreement" shall prepare or cause to be prepared the plans and specifications, advertise for bids, let the construction contract or otherwise provide for the construction of new Traffic Signals and/or reconstruction of existing Traffic Signals (including, at "Municipality Requesting Agreement" option, any special auxiliary equipment, interconnect and/or communication material and equipment), and will supervise construction, reconstruction or betterment work as required by said plans and specifications for the Designated Intersections. All costs of construction and/or reconstruction of new and existing Traffic Signals will be borne by "Municipality Requesting Agreement", and the Traffic Signal system will remain the property of "Municipality Requesting Agreement".

C. It is understood and agreed that it is the responsibility of "Municipality Requesting Agreement" to assume equipment upgrade of the "Municipality Requesting Agreement" Traffic Signal system.

D. It is understood that any additional projects, signals and equipment/software added in the "Municipality Requesting Agreement" will need to be included as additional services

"Host of the maintenance and operations" Responsibilities:

A. "Host of the maintenance and operations" shall provide a trained staff to maintain and operate the traffic signals at the Designated Intersections, within the jurisdictional limits of "Municipality Requesting Agreement" (collectively, "Traffic Signals").

B. "Host of the maintenance and operations" agrees that it shall maintain and operate the Traffic Signals in accordance with the minimum requirements as shown on the Maintenance Checklist in Exhibit-2.

C. "Host of the maintenance and operations" shall maintain, in a log or diary, all emergency calls related to, and routine maintenance of, the Traffic Signals. At a minimum, the log(s) shall indicate the date and time of the call, the repay performed, if any, and the name of the person or entity responding to said call. The log(s) shall be maintained by "Host of the maintenance and operations" for the duration of this Agreement.

D. "Host of the maintenance and operations" shall perform administrative activities and provide administrative services necessary to perform this Agreement.
E. "Host of the maintenance and operations" shall prioritize the repairs of the Traffic Signals based on the public's safety, considering such criteria as the order in which "Host of the maintenance and operations" received the complaint or notice and the amount of traffic at said intersections.
F. The time of response to the Traffic Signal and the repairs, if any, shall be made as based on timelines agreed by the agencies. Unreasonable delays in response or repairs may be a ground for termination of this Agreement.
G. Re-timing for signals shall be performed every XXX months based on the Maintenance Agreement checklist to be attached to this agreement in Exhibit-2.

5. REIMBURSEMENT

The "Municipality Requesting Agreement" shall reimburse the "Host of the maintenance and operations" quarterly, based on an annual amount, for the operation of the traffic signals, as included below:

A. Said reimbursement shall be limited to operational costs, which would include tasks associated with insuring the continuous, safe, and efficient operation of traffic signals, traffic signal systems, and control facilities. Examples include, but are not limited to, operational performance reviews, emergency repairs to system components, periodic evaluation and adjustment to operational timing parameters, computer system and software upgrades, operational upgrades to maintain or improve safety or efficiency, etc.
B. The "Municipality Requesting Agreement" will not reimburse operational costs for activities that do not have a direct and immediate effect on the continuous, safe, and efficient operation of traffic signals, traffic signal systems, and control facilities including, but not limited to, painting of poles and signal cabinets, vegetation control adjacent to facilities, interior and exterior care of traffic control centers and parking areas, furniture for traffic control centers, etc.
C. Any costs incurred by the "Host of the maintenance and operations" prior to written notification by the "Municipality Requesting Agreement" to proceed with the work may not be eligible for reimbursement.
D. The "Host of the maintenance and operations" shall submit a quarterly itemized invoice to "Municipality Requesting Agreement" for said costs no later than three (3) months after the scheduled quarterly invoicing date. This invoice will include the appropriate documentation and reflect the amount due for services performed by the "Host of the maintenance and operations" during the quarter. The "Municipality Requesting Agreement" will reimburse the "Host of the maintenance and operations" each quarter for work performed up to a total annual approved amount of $XXXXXX, unless additional reimbursements are approved by the "Municipality Requesting Agreement". All final invoices must be submitted within one (1) year after the work is performed or said work will be considered non-billable and will not be paid for by the "Municipality Requesting Agreement". The "Municipality Requesting Agreement", at its option, may elect to increase the reimbursement rates shown in the Appendices of this Agreement up to three percent (3%) each year in consideration of inflation rates and cost increases, subject to the availability of funds and the performance of the "Host of the maintenance and operations".
E. The "Municipality Requesting Agreement" shall reimburse the "Host of the maintenance and operations" upon approval by the Department's Division Engineer and the Fiscal Management Section.

F. When a traffic signal covered by this Agreement is damaged by a third party or act of God, “Host of the maintenance and operations” or its designated subcontractor will repair the traffic signal. “Municipality Requesting Agreement” shall pay “Host of the maintenance and operations” for the labor and materials. Then “Municipality Requesting Agreement” will seek reimbursement from the responsible party or insurance company.

G. When police officers are needed to control traffic while work is being performed on a traffic signal in “Municipality Requesting Agreement” under this Agreement, “Host of the maintenance and operations” will not provide police officers or pay for police officers. “Host of the maintenance and operations” will work with “Municipality Requesting Agreement” to arrange for “Municipality Requesting Agreement” police officers to direct traffic.

6. RECORDS AND REPORTS

A. The “Host of the maintenance and operations” shall keep and maintain all books, documents, papers, accounting records, other such cost records and supporting documentation and evidence as may be appropriate to substantiate costs incurred under this Agreement. Further, the “Host of the maintenance and operations” shall make such materials available at its office at all reasonable times during the Agreement period, and for three (3) years from the date of the final payment made under this agreement, for inspection and audit.

EXHIBIT 1: Reimbursement Calculation

Operation and Maintenance of Designated Intersections Expense

“Municipality Requesting Agreement” services for operation and maintenance of the Designated Intersections under this Agreement shall be reimbursed at $X,XXX per Designated Intersection per year. The maximum amount payable per year for operation and maintenance of the Designated Intersections provided in the Exhibit-3 related to Signal Intersections for the agreement is $XXX,XXX

As part of the agreement, “Municipality Requesting Agreement” shall provide all documentation needed to request additional reimbursement from the North Carolina Department of Transportation in such a way that all operations and maintenance costs by “Host of the maintenance and operations” are covered. As part of the agreement, “Municipality Requesting Agreement” agrees to provide payment for services agreed.

Cost of Operations by “Host of the maintenance and operations”	
Cost of Maintenance by “Host of the maintenance and operations”	
Reimbursement from other agencies (DOT for example)	
Total Amount remaining for “Municipality Requesting Agreement”	

Traffic Signal: Design and Construction Support Services Expense

“Host of the maintenance and operations” services to support the design and construction of a traffic signal, paid one time when a project to design and construct a new traffic signal begins, shall be $XX,XXX.

These services are (1) traffic signal design plan review; (2) ordering and invoicing for traffic signal equipment; (3) aiding the traffic signal contractor with traffic signal pole foundation and traffic signal cabinet placement; (4) vehicles detection, communication, and traffic monitoring camera equipment installation; (5) traffic signal timing design and traffic signal controller programming; (6) assisting the contractor with the traffic signal turn-on; (7) inspecting the completed traffic signal and preparing a punch list; and (8) verifying the punch list has been completed.

Additional Services: On Call

“Host of the maintenance and operations” may provide additional services for “Municipality Requesting Agreement” traffic signal system, beyond what is defined in the Maintenance Agreement Form. For additional services “Municipality Requesting Agreement” will issue a work order to “Host of the maintenance and operations”. Each work order shall include a description of the work, estimated labor costs, and estimated material cost. Labor costs will include overhead. Once the project is completed, “Municipality Requesting Agreement” shall pay “Host of the maintenance and operations” the actual labor and actual material cost, even if these costs exceed the estimate.

EXHIBIT 2 : Operational Performance Review Checklist

MUNICIPAL OPERATIONS AGREEMENT
Operational Performance Review Checklist – Traffic Signals
“Municipality Requesting Agreement”

		Interval of Performance Measure		
		6 MO	12 MO	2 YEARS
Cabinet	Lubricate hinges and lock			
	Replace Filters			
	Check Door Gasket			
	Check Anchor Bolts / Extension Bolts			
	Check for water seepage, dust accumulation; reseal base if needed			
	Check Grounding Resistance and Bonding Connections and Conductors			
	Check for current wiring schematics, Signal plans, and Maintenance Records			
	Check condition and operation of fan and thermostat			
	Check ground fault receptacle and insure no control equipment plugged into receptacle			
	Measure service voltage			
	Check interior lamps; replace as required			
	Check physical condition of meter / service disconnect			
	Clean and vacuum Cabinet			
	Visually check Line Filter and surge arrester			
	Inspect Foundation and exterior for damage, vandalism, and the presence and condition of signal inventory number			
	Test police panel switches			
	Place insect and/or rodent poison in cabinet if infestation is present			
Conflict Monitor	Verify conflict monitor certification date is within 12 months			
	Perform field check of operation. Remove load switch to create red fail and observe response of monitor. Ensure stop timing is implemented.			
Load Switches/ Flashers	Check load switches and flashers for tight and secure fit into the socket			
	Check operation of all indicator lights			
Auxiliary Logic	Check for operation as per signal plans			

MUNCIPAL OPERATIONS AGREEMENT
Operational Performance Review Checklist – Traffic Signals
"Municipality Requesting Agreement"

		Interval of Performance Measure		
		6 MO	12 MO	2 YEARS
Relays	Visually inspect condition of all relays and replace if necessary			
Terminal Connections	Check for discoloration and corrosion			
	Tighten all terminal connections			
	Check labels and replace as needed			
	Check programming of red monitor jumpers if present			
	Check condition of all loading resistors			
Controllers	Verify date and time, correct any discrepancies (if applicable)			
	Verify programming parameters			
	Verify proper software version			
	Verify operation per signal plan (phasing operation, timings, signal head display, pavement markings, etc.)			
	Check all harnesses and connections			
	Verify proper operation of any preemption circuits			
	Check operation of display and backlight			
	Check time clock settings			
	Check that Posted Speed Limit matches signal plan			
Detection Sensors	Inspect condition of all inductive loops and lead ins; Repair/replace as needed			
	Verify proper operation of detection sensors, meg; replace or repair as needed			
	Verify loop lead in cable is twisted in cabinet			
	Check loop lead-ins for correct labeling and phase assignments			
	Check alignment and proper operation of all out of street detection			
Detector Units	Check detector for proper operation and sensitivity			
	Verify stretch and delay programming and operation			

MUNCIPAL OPERATIONS AGREEMENT
Operational Performance Review Checklist – Traffic Signals
"Municipality Requesting Agreement"

		Interval of Performance Measure		
		6 MO	12 MO	2 YEARS
Pedestrian Push Buttons	Check and actuate push buttons on all approaches of actuated crosswalks and visually verify pedestrian signal operation (Verify operation of all push buttons)			
	Check push button lamp (if applicable) for operation			
	Check push button alignment and accessibility			
	Check audio operation and direction			
	Check push button signs; clean or replace if necessary			
Pedestrian Heads	Re-lamp incandescent bulbs or replace LEDs if needed			
	Check condition, alignment and operation			
	Clean lenses and reflectors			
Signal Heads and Blank Out Signs	Check for proper alignment, operation, and condition			
	Check condition of back plates (if used)			
	Check for proper height			
	Clean lenses, signs and LED modules; replace as needed			
	Check for wear on the span wire and signal mounting hardware			
Metal Poles and Mast Arms	Inspect for rust and spot paint as required			
	Inspect joints for rust and cracks at arm/upright location and at base plate			
	Visually inspect anchor bolts and mast arm bolts for condition and tightness			
	Check pole grounding and connections			
	Inspect for damage; document and report any damage found.			
	Check and secure pole caps and hand hole covers			
	Inspect all wiring and conduit in pole			
	Visually inspect condition of foundation			

MUNCIPAL OPERATIONS AGREEMENT
Operational Performance Review Checklist – Traffic Signals
"Municipality Requesting Agreement"

OTHER POSSIBLE SERVICES/TECHNOLOGY		Interval of Performance Measure						
		DAILY	WEEKLY	MONTHLY	3 MO	6 MO	12 MO	2 YEARS
ATSPM	Monitor of data from ATSPM detection Systems and reporting							
Real Time Monitoring	Monitoring system in real time							
Signal Retiming	Providing services for retiming signal corridors							
Signal Construction Support	Providing technical support							
	Providing plan reviews							
	Providing designs							
	Providing construction administration services							
	Providing implementation services							
Other Technologies	ATSPM							
	Real time monitoring							

EXHIBIT 3: Agreement Signals/Devices

	Signal/Device Location (Intersection streets)	State ID/Municipality ID	Communications Owner
1			
2			
3			
4			
5			
6			
7			
8			
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24			
25			
26			

Appendix C

CCTV PM

Date: ____ Start Time: __ Finish Time: __________ Technicians:

LOCATION :

	CABINET	**COMPLETED**	**PM INTERVAL**
1	Lubricate hinges and locks		every 3 months
2	Clean Filters		every 3 months
3	Replace Filters		every 6 months
4	Check Weatherproof Seal		every 3 months
5	Check Anchor Bolts		every 3 months
6	Check for water accumulation and duct sealant		every 3 months
7	Check Ground Rod Clamp and Connections		every 3 months
8	Check Ground Resistance (20ohms or less)		every 3 months
9	Check Current Wiring Schematics and History Records		every 3 months
10	Check Operation of Fan and Thermostat		every 3 months
12	Check Ground Fault Receptacle		every 3 months
13	Check for proper Service Voltages at Cabinet Entrance Point		every 3 months
14	Check Operation of Cabinet Lighting		every 3 months
15	Check Meter/Disconnect		every 3 months
16	Vaccuum Inside Cabinet		every 3 months
17	Check Cable Labels		every 3 months
18	Apply Ant & Roach Spray		every 3 months
19	Check Cabinet Documentation		every 3 months
	CAMERA	**COMPLETED**	**PM INTERVAL**
1	Check Zoom, Pan and Tilt		every 3 months
2	Clean Lens and Dome		every 3 months
3	Ensure housing is secure to pole		every 3 months
	TERMINAL CONNECTIONS	**COMPLETED**	**PM INTERVAL**
1	Check for Discoloration and Tightness		every 3 months
2	Check for Signs of Corrosion		every 3 months
3	Tighten all terminal Connections		every 3 months
	CONTROL EQUIPMENT	**COMPLETED**	**PM INTERVAL**
1	Check if all Indicators are Working Properly		every 3 months
2	Check if Connectors are Tight and Secure		every 3 months
3	Check for Proper Modem Operation		every 3 months
4	Dust off all equipment		every 3 months
	POLES	**COMPLETED**	**PM INTERVAL**
1	Inspect for rust, spot paint as needed		every 3 months
2	Inspect joints for rust and cracks		every 3 months
3	Inspect pole base for rust or cracks		every 3 months
4	Inspect anchor bolts for rust and tightness		every 3 months
	JUNCTION BOXES AND HANDHOLES	**COMPLETED**	**PM INTERVAL**
1	Check integrity of splice		every 3 months
2	Check ground rod and clamp connection		every 3 months
3	Check bonding of conduits		every 3 months
4	Check for abnormal amount of water		every 3 months
5	Check lid for condition and fit		every 3 months
6	Clear pull box of over growth		every 3 months
	FIBER OPTICS	**COMPLETED**	**PM INTERVAL**
1	Inspect overhead slack loop		every 3 months
2	Verify operation of fiber optic transceiver		every 3 months
3	Clean fiber optic connectors		every 6 months
4	Inspect splice locations		every 6 months
	MATERIALS	**QTY.**	**PM INTERVAL**
1	*10x16 filter*		every 3 months
2	*stainless steel cleaner*		every 3 months
3	*crc lubricant*		every 3 months
4	*bug spray*		every 3 months
5	*duct seal (lb.)*		every 3 months
6			
7			
8			

Town of Cary

INTERSECTION PM

Date: **Start Time:** **Finish Time:** **Technicians:** **TRUCK 0011**

LOCATION : ________________________

	CABINET	COMPLETED	PM INTERVAL
1	Lubricate hinges and locks		every 3 months
2	Clean Filters		every 3 months
3	Replace Filters		every 6 months
4	Check Weatherproof Seal		every 3 months
5	Check Anchor Bolts		every 3 months
6	Check for water accumulation and duct sealant		every 3 months
7	Check Ground Rod Clamp and Connections		every 3 months
8	Check Ground Resistance (20ohms or less)		every 3 months
9	Check Current Wiring Schematics and History Records		every 3 months
10	Check Operation of Fan and Thermostat		every 3 months
12	Check Ground Fault Receptacle		every 3 months
13	Check for proper Service Voltages at Cabinet Entrance Point		every 3 months
14	Check Operation of Cabinet Lighting		every 3 months
15	Check Meter/Disconnect		every 3 months
16	Vaccuum Inside Cabinet		every 3 months
17	Check Cable Labels		every 3 months
18	Apply Ant & Roach Spray		every 3 months
19	Check Cabinet Documentation		every 3 months
	CONFLICT MONITOR	**COMPLETED**	**PM INTERVAL**
1	Check Start-Up Flash Time		every 3 months
	LOAD SWITCHES	**COMPLETED**	**PM INTERVAL**
1	Check for Tight Fit		every 3 months
2	Check Indicators on Front Panel		every 3 months
	AUXILIARY LOGIC		**PM Interval**
1	Check Operation		every 3 months
	RELAYS	**COMPLETED**	**PM INTERVAL**
1	Check Mercury Relays		every 3 months
2	Check for Burned or Pitted Contacts		every 3 months
3	Check for Tight and Secure Fit into Sockets		every 3 months
	FLASHERS	**COMPLETED**	**PM INTERVAL**
1	Check for Tight and Secure Fit into Socket		every 3 months
2	Check Flash Rate		every 3 months
3	Check Operation		every 3 months
	SWITCHES	**COMPLETED**	**PM INTERVAL**
1	Check for Burnt or Loose Wiring		every 3 months
2	Verify Operation of each Switch		every 3 months
	TERMINAL CONNECTIONS	**COMPLETED**	**PM INTERVAL**
1	Check for Discoloration and Tightness		every 3 months
2	Check for Signs of Corrosion		every 3 months
3	Tighten all terminal Connections		every 3 months
	CONTROL EQUIPMENT	**COMPLETED**	**PM INTERVAL**
1	Verify Date and Time		every 3 months
2	Verify Programming		every 3 months
3	Verify Controller Operating in Proper Mode		every 3 months
4	Check if all Indicators are Working Properly		every 3 months
5	Check for Extension by Detector Activation		every 3 months
6	Check Modules for tight and Secure Fit		every 3 months
7	Check if Connectors are Tight and Secure		every 3 months
8	Check for Proper Modem Operation		every 3 months
10	Dust off all equipment		every 3 months

	DETECTORS	COMPLETED	PM INTERVAL
1	Inspect roadway loops for exposed wiring		every 3 months
2	Meg loops		every 3 months
3	Check resistance		every 3 months
4	Check lead-in cable		every 3 months
5	Check Mounting Brackets		every 3 months
	DETECTOR UNITS	**COMPLETED**	**PM INTERVAL**
1	Check detector unit for loop Activation		every 3 months
2	Check Connectors for Secure Fit		every 3 months
3	Verify timing (stretch,delay)		every 3 months
4	Verify call inputs to Controller		every 3 months
5	Verify date and time functions		every 3 months
6	Verify software/hardware operation (if applicable)		every 3 months
7	Verify data collection (if applicable)		every 3 months
	PUSH BUTTONS	**COMPLETED**	**PM INTERVAL**
1	Check and actuate push buttons on all approaches to verify correct operation		every 3 months
2	Verify Controller Pedestrian timing		every 3 months
3	Check push button signs, clean as needed		every 3 months
4	Check push button alignment		every 3 months
5	Check audio operation and direction		every 3 months
	PEDESTRIAN HEADS	**COMPLETED**	**PM INTERVAL**
1	Clean lenses, signs and reflectors		every12 months
2	Replace lamps		every12 months
3	Check for cracks or rust in hardware		every 6 months
4	Check for bent visors, wing nuts, hinges		every 6 months
5	Check locking ring		every 6 months
	SIGNAL HEADS	**COMPLETED**	**PM INTERVAL**
1	Clean lens, reflectors, signs		every12 months
2	Replace lamps		every12 months
3	Check alignment		every 3 months
4	Check for wear on the span wire, signal wire and mechanical hardware		every 6 months
5	Check mast arms, free-swinging signals, check clevis and pins		every 6 months
6	Check for cracks or rust in hardware		every 6 months
7	Check for bent visors, wing nuts hinges		every 6 months
8	Check locking ring		every 6 months
9	Check backplates		every 6 months
10	Check for proper height		every 3 months
	MAST ARMS & POLES	**COMPLETED**	**PM INTERVAL**
1	Inspect for rust, spot paint as needed		every 3 months
2	Inspect joints for rust and cracks		every 3 months
3	Inspect pole base for rust or cracks		every 3 months
4	Inspect anchor bolts for rust and tightness		every 3 months
	SPAN WIRE AND POLES (WOOD)		**PM INTERVAL**
1	Check poles for splitting		every 3 months
2	Check pole below grade for rot		every 6 months
3	Check span wire for rust		every 3 months
4	Check clamps and hardware		every 6 months
5	Check guy wire, anchors nad guards		every 3 months
6	Verify all spans are bonded to pole ground		every 6 months
7	Check pole grounding and connections		every 6 months
	JUNCTION BOXES AND HANDHOLES	**COMPLETED**	**PM INTERVAL**
1	Check integrity of splice		every 3 months
2	Check ground rod and clamp connection		every 3 months
3	Check bonding of conduits		every 3 months
4	Check for abnormal amount of water		every 3 months
5	Check lid for condition and fit		every 3 months
6	Clear pull box of over growth		every 3 months
	FIBER OPTICS	**COMPLETED**	**PM INTERVAL**
1	Inspect overhead slack loop		every 3 months
2	Verify operation of fiber optic transceiver		every 3 months
3	Clean fiber optic connectors		every 6 months
4	Inspect splice locations		every 6 months

	MATERIALS	QTY.	PM INTERVAL
1			every 3 months
2			every 3 months
3			every 3 months

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MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE C

Traffic Signal Operations Program TOWN OF CARY

NOTE: The Department requires the Municipality to maintain a Level of Service "C", or "good", in order to provide reimbursement. If the operation falls below a Level of Service "C", or "good", then the Department may withhold reimbursement under this Agreement. The Department will not reimburse the Municipality for any associated additional costs if the Municipality elects to operate the signals at a higher level of service.

Key Components of a "Good" Level of Service:

1. Maximum Emergency Response Times
    - Trouble calls – 4 hours
    - Repair Knockdowns – 8 hours
    - Absence of a signal indication – Next working day
    - Repair/replace inoperative loops – 15 calendar days
2. Operational Performance Reviews
    - Perform the required minimum tasks at 6-month, 12-month and two-year intervals
    - Replace LED modules after 5 years of service
3. System Component Repairs
    - Repair equipment in a timely manner to support emergency and operational needs
    - Upgrade equipment firmware as appropriate to address items affecting operational efficiency and safety
    - Certify the proper operation of conflict monitors/malfunction management units on an annual basis

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MUNCIPAL OPERATIONS AGREEMENT – SCHEDULE C

Operational Performance Review (OPR) Checklist – Traffic Signals

TOWN OF CARY

		Interval		
		6 MO	**12 MO**	**2 YEARS**
Cabinet	Lubricate hinges and lock	x		
	Replace Filters	x		
	Check Door Gasket	x		
	Check Anchor Bolts / Extension Bolts	x		
	Check for water seepage, dust accumulation; reseal base if needed	x		
	Check Grounding Resistance and Bonding Connections and Conductors	x		
	Check for current wiring schematics, Signal plans, and Maintenance Records	x		
	Check condition and operation of fan and thermostat	x		
	Check ground fault receptacle and insure no control equipment plugged into receptacle	x		
	Measure service voltage	x		
	Check interior lamps; replace as required	x		
	Check physical condition of meter / service disconnect	x		
	Clean and vacuum Cabinet	x		
	Visually check Line Filter and surge arrester	x		
	Inspect Foundation and exterior for damage, vandalism, and the presence and condition of signal inventory number	x		
	Test police panel switches		x	
	Place insect and/or rodent poison in cabinet if infestation is present	x		
Conflict Monitor	Verify conflict monitor certification date is within 12 months	x		
	Perform field check of operation. Remove load switch to create red fail and observe response of monitor. Ensure stop timing is implemented.		x	
Load Switches / Flashers	Check load switches and flashers for tight and secure fit into the socket	x		
	Check operation of all indicator lights	x		
Auxiliary Logic	Check for operation as per signal plans	x		

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MUNCIPAL OPERATIONS AGREEMENT – SCHEDULE C

Operational Performance Review Checklist – Traffic Signals

		Interval		
		6 MO	**12 MO**	**2 YEARS**
Relays	Visually inspect condition of all relays and replace if necessary	x		
Terminal Connections	Check for discoloration and corrosion	x		
	Tighten all terminal connections	x		
	Check labels and replace as needed	x		
	Check programming of red monitor jumpers if present	x		
	Check condition of all loading resistors	x		
Controllers	Verify date and time, correct any discrepancies (if applicable)	x		
	Verify programming parameters	x		
	Verify proper software version	x		
	Verify operation per signal plan (phasing operation, timings, signal head display, pavement markings, etc.)	x		
	Check all harnesses and connections	x		
	Verify proper operation of any preemption circuits	x		
	Check operation of display and backlight	x		
	Check time clock settings	x		
	Check that Posted Speed Limit matches signal plan	x		
Detection Sensors	Inspect condition of all inductive loops and lead ins; Repair/replace as needed	x		
	Verify proper operation of detection sensors, meg; replace or repair as needed	x		
	Verify loop lead in cable is twisted in cabinet	x		
	Check loop lead-ins for correct labeling and phase assignments	x		
	Check alignment and proper operation of all out of street detection	x		
Detector Units	Check detector for proper operation and sensitivity	x		
	Verify stretch and delay programming and operation	x		

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MUNCIPAL OPERATIONS AGREEMENT – SCHEDULE C

Operational Performance Review Checklist – Traffic Signals

		Interval		
		6 MO	**12 MO**	**2 YEARS**
Pedestrian Push Buttons	Check and actuate push buttons on all approaches of actuated crosswalks and visually verify pedestrian signal operation (Verify operation of all push buttons)	x		
	Check push button lamp (if applicable) for operation	x		
	Check push button alignment and accessibility	x		
	Check audio operation and direction	x		
	Check push button signs; clean or replace if necessary	x		
Pedestrian Heads	Re-lamp incandescent bulbs or replace LEDs if needed		x	
	Check condition, alignment and operation	x		
	Clean lenses and reflectors			x
Signal Heads and Blank Out Signs	Check for proper alignment, operation, and condition	x		
	Check condition of back plates (if used)	x		
	Check for proper height	x		
	Clean lenses, signs and LED modules; replace as needed			x
	Check for wear on the span wire and signal mounting hardware			x
Metal Poles and Mast Arms	Inspect for rust and spot paint as required		x	
	Inspect joints for rust and cracks at arm/upright location and at base plate		x	
	Visually inspect anchor bolts and mast arm bolts for condition and tightness		x	
	Check pole grounding and connections		x	
	Inspect for damage; document and report any damage found.		x	
	Check and secure pole caps and hand hole covers		x	
	Inspect all wiring and conduit in pole		x	
	Visually inspect condition of foundation		x	

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MUNCIPAL OPERATIONS AGREEMENT – SCHEDULE C

Operational Performance Review Checklist – Traffic Signals

		Interval		
		6 MO	**12 MO**	**2 YEARS**
Wood Poles and Span Wire	Check pole for splitting	x		
	Check pole below grade for rot	x		
	Check clamps and all hardware	x		
	Check guy wire, anchors, and guards; repair if needed	x		
	Verify all spans are bonded to pole ground	x		
	Check pole grounding and connections	x		
Pull Boxes	Check the ground rod, clamp connection, and bonding of conduits if applicable		x	
	Check all cables in pull box for pinching by lid, including level of pull box		x	
	Check for abnormal amount of water; verify proper drainage		x	
	Check lid for abnormal condition and fit		x	
Systems Equipment	Ensure the controller operates in mode selected by master		x	
	Check any special equipment (transceivers, etc.) for proper operation		x	
	Disconnect controller from master and check for free or backup operation		x	
Conduit	Visually inspect all conduits; repair as needed		x	
Pavement Markings	Verify that pavement markings match intersection plans	x		
	Inspect condition of pavement markings	x		

APPENDIX I

MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE DTOWN OF CARY

Traffic Signal System Operations

NOTE: The Department requires the Municipality to maintain a Level of Service "C", or "good", in order to provide reimbursement. If the operation falls below a Level of Service "C", or "good", then the Department may withhold reimbursement under this Agreement. If the Municipality operates at a higher level of service, the Department will not reimburse these costs.

Levels of Service

Level-of-service "A"

1. All of the signalized intersections in the Municipality's jurisdiction are monitored by the system. All of the signalized intersections are actively controlled for at least some periods of the day (e.g. timing plans are developed and implemented).

2. All timing plans and day plans are evaluated on intervals of no greater than **six months**. On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified **annually**. Required new plans are developed and implemented within **three months** of identification.

3. The Municipality has an active traffic data collection program that includes turning movement counts at all signalized intersections; the collection of average daily traffic counts; and performs travel-time/delay studies on all subsystems at **a minimum of every two years**. This data is used to evaluate system operations and performance.

4. Timing plans for newly installed intersections are implemented in conjunction with the installation of the traffic signal.

5. The Municipality has an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated on intervals of **no less than two times per year**.

6. A minimum of 90% of all system detectors are operational at any given time. The maximum time to repair failed detection devices is **30 calendar days**.

7. The control center is staffed by qualified personnel during the AM & PM peak hours, and during other times of high traffic volumes (e.g. special events).

8. The Municipality uses traffic responsive timing plans where appropriate and continually monitors and updates the thresholds.

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MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE D

Traffic Signal System Operations

Level-of-service "B"

1. Essentially all (+90%) of the signalized intersections in the Municipality's jurisdiction are monitored by the system. Practically all (+95%) of the monitored signalized intersections are actively controlled.

2. All timing plans and day plans are evaluated on intervals of no greater than **12 months**. On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified annually. Required new plans are developed and implemented **within three months** of identification.

3. The Municipality has an active traffic data collection program that includes turning movement counts at all signalized intersections; the collection of average daily traffic counts; and performs travel-time/delay studies on all subsystems at **a minimum of every two years**. This data is used to evaluate system operations and performance.

4. Timing plans for newly installed intersections are implemented in conjunction with the installation of the traffic signal.

5. The Municipality has an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated on intervals of **no less than two times per year**.

6. A minimum of 85% of all system detectors is operational at any given time. The maximum time to repair failed detection devices is **30 calendar days**.

7. The control center is staffed by qualified personnel during the AM & PM peak hours. The operations staff is on-call during other times of expected high traffic volume.

8. The Municipality uses traffic responsive timing plans where appropriate. Threshold values are evaluated **annually**.

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MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE D

Traffic Signal System Operations

Level-of-service "C"

1. The vast majority (+80%) of the signalized intersections in the Municipality's jurisdiction are monitored by the system. The only traffic signals not monitored are those whose lack of proximity does not lend them to cost-effective communication. The vast majority (+80%) of monitored signals are actively controlled by the system.

2. All timing plans and day plans are evaluated on intervals of no greater than **18 months.** On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified **annually**. On average, required new plans are developed and implemented within **six months** of identification.

3. The Municipality obtains the data that is used to evaluate system operations and performance.

4. Timing plans for newly installed intersections are implemented within **30 calendar days** of the installation of the traffic signal.

5. The Municipality has an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated on intervals of **no less than two times per year**.

6. A minimum of 80% of all system detectors are operational at any given time. The maximum time to repair failed detection devices is **60 calendar days**.

7. The control center is staffed by qualified personnel during the AM & PM peak hours. The operations staff is on-call during other times of expected high traffic volume.

8. The Municipality uses traffic responsive timing plans where appropriate. Threshold values are evaluated **annually**.

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MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE D

Traffic Signal System Operations

Level-of-service "D"

1. Most (+60%) of the signalized intersections in the Municipality's jurisdiction are monitored by the system. Signalized intersections that are in close proximity to other signalized intersections (<0.5 mile) are in operation but are not monitored by the system. Most (+60%) of the monitored signals are actively controlled by the system.
2. All timing plans and day plans are evaluated on intervals of no greater than 24 months. On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified on intervals of no greater than **two years**. New plans are developed and implemented within **12 months** of identification.
3. The Municipality obtains the data is used to evaluate system operations and performance.
4. Timing plans for newly installed intersections are implemented within **60 calendar days** of the installation of the traffic signal.
5. The Municipality has an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated on intervals of **no less than one time per year**.
6. A minimum of 60% of all system detectors are operational at any given time. The maximum time to repair failed detection devices is **90 calendar days**.
7. The control center is staffed during either the AM or PM peak hour; whichever is the highest volume period.
8. The Municipality has not evaluated the use of traffic responsive timing plans.

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MUNICIPAL OPERATIONS AGREEMENT – SCHEDULE D

Traffic Signal System Operations

Level-of-service "F"

1. Less than half (<50%) of the signalized intersections in the Municipalities' jurisdiction are monitored by the system. Signalized intersections that are in close proximity to other signalized intersections (<0.5 mile), are in operation but are not monitored by the system. Most (+60%) of the monitored signals are actively controlled by the system.

2. All timing plans and day plans are evaluated on intervals greater than **30 months**. On corridors with a significant annual growth in traffic volume (> 5.0%), new timing plans are identified on intervals of no greater than **two years**. On average, new plans are developed and implemented on intervals **not to exceed 18 months** after identification.

3. The Municipality does not collect data to evaluate system performance and retime signals. All data used is provided by others.

4. Timing plans for newly installed intersections are implemented **more than 90 calendar days** after installation of the traffic signal.

5. The Municipality does not have an active, on-going operational performance program for operation of the traffic signal system in which system communication components and central site hardware is tested and evaluated. The Municipality provides emergency restoration only for system communication and hardware components.

6. A minimum of 50% of all system detectors are operational at any given time. The maximum time to repair failed detection devices is **120 calendar days**.

7. The control center is staffed during either the AM or PM peak hour; whichever is the highest volume period.

8. The Municipality has not evaluated the use of traffic responsive timing plans.