Priority Area Three: Transit Signal Priority

Vision: Transit vehicles are able to benefit from Transit Signal Priority (TSP) across various jurisdictions in the region, regardless of home agency and the Computer Aided Dispatch (CAD) / Automated Vehicle Locator (AVL) system installed on the vehicle.

Objective: Identify recommended steps that allow transit agencies to procure TSP solutions that provide a future path to interoperability of multiple TSP systems.

Initial Findings & Opportunities

Summary of Current Conditions

Transit Signal Priority (TSP) systems have been deployed in the Triangle region along several different transit routes and corridors. These routes are summarized in Table 5-1 for reference. Figure 5-1 illustrates the locations of the routes and TSP deployments in the region.

Table 5-1: Summary of Existing and Planned TSP Deployments in the Region

Transit Agency / TSP Routes	Traffic Agency	TSP System Vendor	Signal Locations	# of Buses	TSP Conditions
GoCary Route 5 (Kildaire Farm Rd.)	Town of Cary	Applied Information	Along Route 5	Total of 5 buses on Route 5	Behind schedule by 1 minute
GoDurham Route 5 (Fayetteville St.)	City of Durham	Applied Information	Along Route 5	Route 5 buses	Behind schedule
GoRaleigh Route 15 (WakeMed) – Future Bus Rapid Transit (BRT) on New Bern Avenue	City of Raleigh	EMTRAC	16 signals along Route 15	Route 15 buses	Behind schedule by 1 minute
NCSU Wolfline (All campus buses)	City of Raleigh	Yunex Traffic for CV devices	27 signals on campus	35 buses in fleet	Behind schedule by 4 minutes
Planned - North-South BRT	Town of Chapel Hill	TBD	Along NSBRT Route	NSBRT Buses on Corridor	TBD

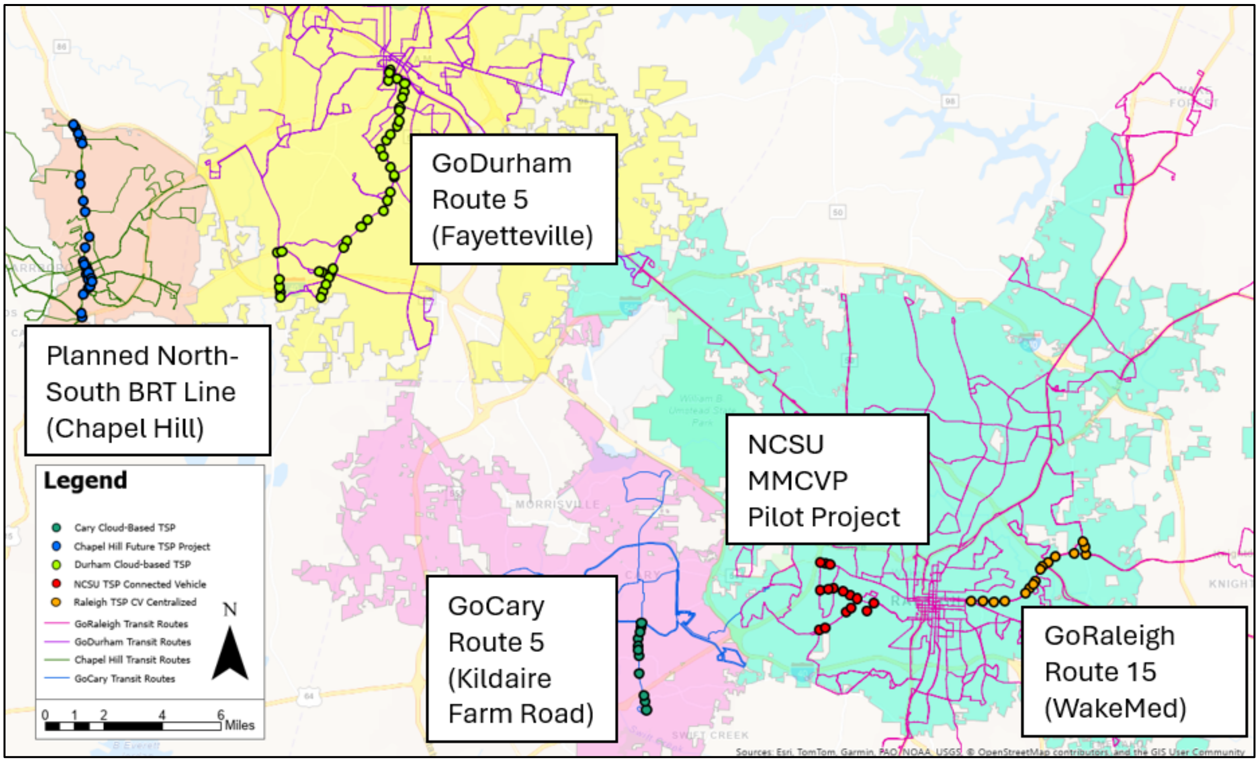


Figure 5-1 – Locations of Existing and Planned TSP Deployments in the Research Triangle Region

These systems and their locations are described in detail in the following sections.

Existing TSP System: Applied Information (AI)

Locations: GoCary Route 5 (Kildaire Farm Road); GoDurham Route 5 (Fayetteville Street)
Description: Applied Information (AI) has provided a traffic management system solution for Cary, Durham, Apex, and Morrisville that allows for central office staff to remotely monitor traffic signal operations through cloud-based software and cellular communications with traffic signals in those jurisdictions. This system allows for TSP operations that requires hardware installed on a select number of buses to facilitate the communication of TSP requests through the cloud-based software management system that allows for monitoring and configuration of TSP operations. All traffic signals in Cary, Durham, Apex, and Morrisville are equipped with the intersection equipment from the vendor (AI) that can enable TSP operations on all routes in those jurisdictions.

TSP hardware on buses is integrated with the existing Automated Vehicle Locator (AVL) hardware for the purposes of receiving schedule adherence-based activations requests to enable TSP at traffic signals along a route. Town of Cary has installed an AVL system known as TripSpark, while City of Durham has installed an AVL system from Avail Technologies. Once a bus is behind schedule, the AVL system will send a signal to the TSP hardware which will then use cellular communications to send a TSP request to the next traffic signal on the route to the cloud-based TSP software, which will, in turn, relay the TSP request to TSP hardware in the appropriate traffic signal cabinet.

The AI TSP system also has a redundant communications feature for both Cary and Durham that allows TSP hardware on the bus to send TSP requests directly to traffic signal cabinets using a 900 MHz radio installed on buses. This redundancy is beneficial in the event of a loss in cellular signal or reception along the transit routes. Refer to Figure 5-2 for an illustration of the communication paths for TSP requests made from buses to intersections in Cary and Durham.

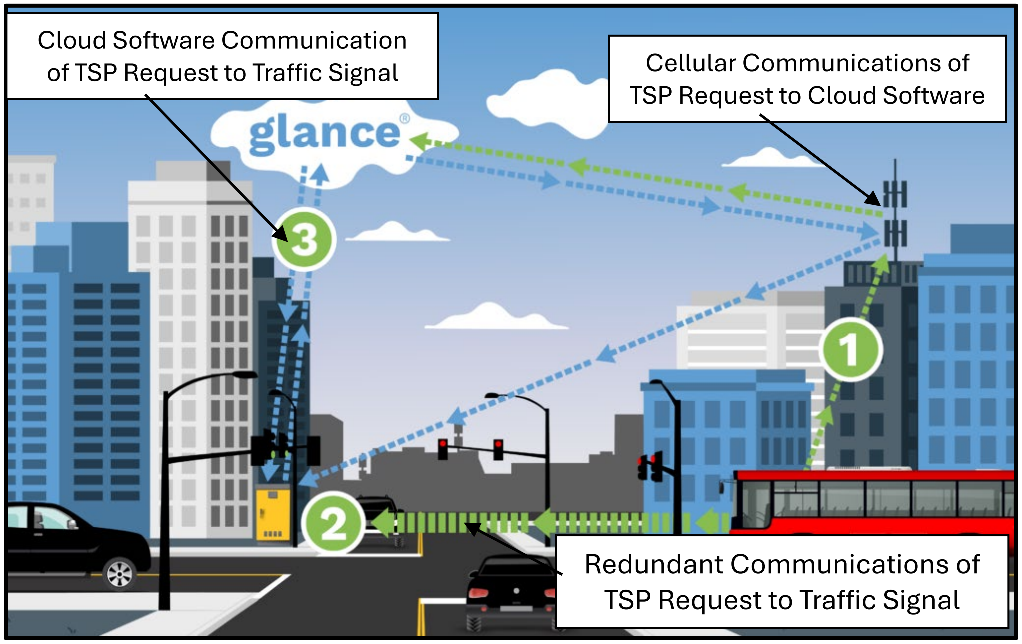


Figure 5-2 – Communications Overview Diagram of Cary and Durham TSP Systems
Source: Applied Information

The Town of Cary has installed TSP equipment on five buses as part of a pilot project along the Route 5 (Kildaire Farm Road) which is a high ridership route in Cary. These five buses are programmed to make TSP requests when AVL system has detected the buses running at least 1 minute behind schedule. These five buses are also interlined with other Cary routes, so not all buses along the Route 5 corridor are necessarily equipped with the on-board TSP hardware that will enable them to make TSP requests.

However, even with this limitation, Cary has seen a 3% improvement in On-Time Performance and a 1 minute reduction in transit running times along the Route 5 through review of transit data from its AVL vendor (TripSpark) in April and May 2025. While these improvements are relatively small, the time is still important for passengers that may be making transfer connections to other routes at the Town of Cary Depot that are tightly scheduled to arrive at the Depot within minutes of each other.

The Town of Cary will continue to review transit On-Time Performance (OTP) and running time data gathered from their AVL vendor throughout 2025 prior to making future decisions about installing additional on-board TSP hardware on more buses. While there is hardware currently installed at all signalized intersections in Cary to provide for both TSP and Emergency Vehicle Pre-emption (EVP), there would need to be TSP signal timing parameters developed by the Town of Cary and input onto the controllers that would provide sufficient time for buses to traverse those intersections during TSP requests. This process can be done remotely though by traffic staff with the appropriate traffic software that allows them to communicate with traffic signal controllers.

In addition to these TSP systems, the vendor AI has also equipped all traffic signals in the Towns of Apex and Morrisville with intersection equipment that enables Emergency Vehicle Pre-emption

(EVP) for all police vehicles in those two jurisdictions. The same AI system that provides emergency vehicles with pre-emption can also provide transit vehicles with signal priority requests. Refer to Figure 5-5 later in the document for an overview map of the signals at which TSP has been implemented, and the other signal locations that are capable of TSP within these jurisdictions.

There is also a planned project from FY2028 through 2030 that proposes an annual traffic signal system operation and maintenance agreement between the Towns of Apex, Holly Springs and Fuquay-Varina. This will help support additional responsibilities of signal maintenance staff in the area as TSP operations expand to additional transit routes in the area.

The Applied Information cloud-based TSP system in Figure 5-3 has a large deployment in the region that covers all traffic signals in the City of Durham and the Towns of Cary, Morrisville, and Apex, given that the vendor's equipment is also used to support traffic signal operations and Emergency Vehicle Preemption in those jurisdictions.

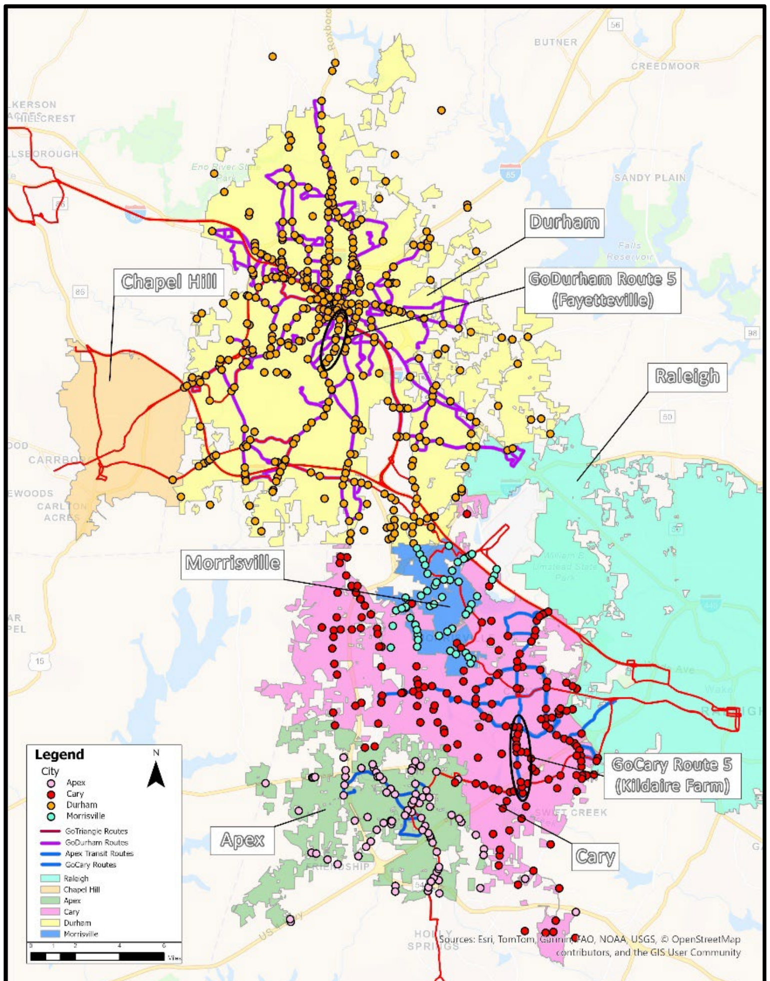


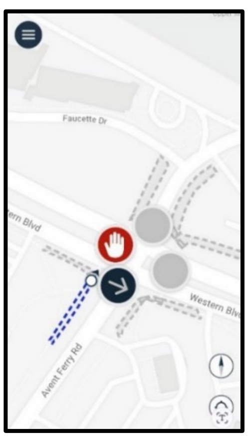
Figure 5-3 – Deployment of Applied Information Cloud-Based System for TSP / EVP

Existing TSP System: Multi-Modal Connected Vehicle Pilot (MMCVP)

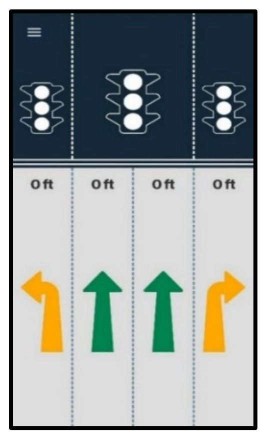
Locations: North Carolina State University (NCSU) Campus at 26 traffic signals
Description: This is a pilot project led by the North Carolina Department of Transportation (NCDOT) in partnership with NCSU Wolfline buses, the City of Raleigh, and other agency stakeholders in the area. This project features the installation of Connected Vehicle (CV) technology on NCSU Wolfline buses that will send TSP requests that follow a message format defined by Society of Automotive Engineers (SAE) under a J2735 standard to CV Roadside Unit (RSU) equipment installed at traffic signals. TSP requests are only activated when the AVL system on NCSU buses detects the bus to be behind its posted schedule by more than 4 minutes, and TSP requests conforming to an NTCIP 1211 standard for signal controllers are sent from the RSU down to the controller. The CV hardware vendor for the pilot project is from Yunex Traffic, and the project will be evaluated by the NCSU Institute for Transportation Research and Education upon its completion in summer / fall of 2026.

The MMCVP Project is also using CV equipment at a select number of traffic signals with high pedestrian crossings to communicate alerts to pedestrians about vehicles traveling along the roadway on the NCSU campus. These alerts are provided through a mobile application that was developed for the MMCVP project to demonstrate the potential of providing notifications to pedestrians through smartphones about approaching vehicles that pedestrians may not see at an intersection. Figure 5-4 presents a view of the CV equipment and mobile application, and Figure 5-5 presents a map of the 27 intersections at which CV equipment has been installed.

Western Blvd. and Avent Ferry Rd. Traffic Signal and CV Equipment for TSP Operations and Mobile Application for Pedestrians / Motorists



Pedestrian View of Mobile Application at Intersection



Motorist View of Mobile Application at Intersection

Figure 5-4 – MMCVP Project Equipment and Mobile Application at Western Blvd. and Avent Ferry Road Intersection on NCSU Campus

Source: *Yunex YU2X.*

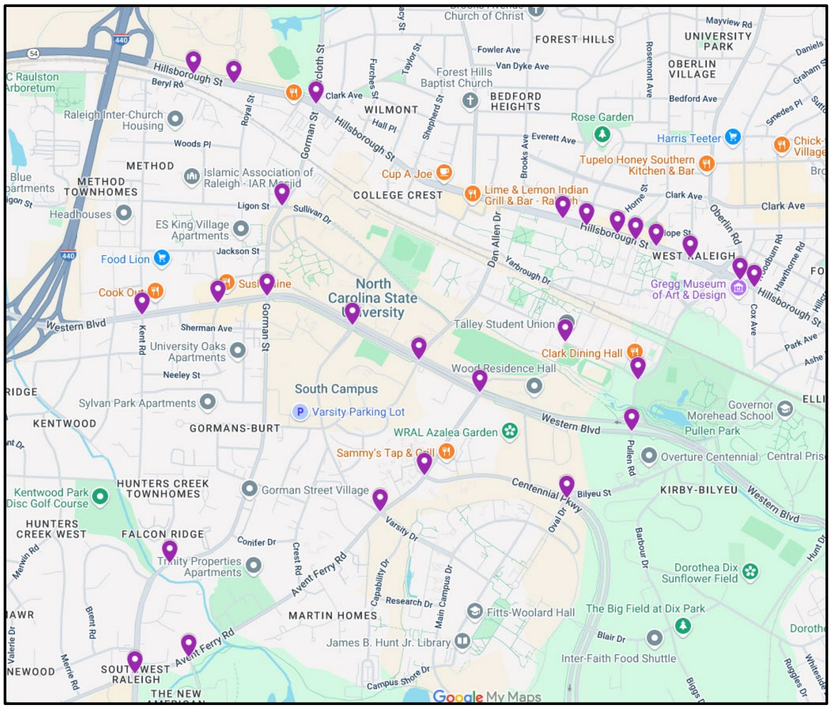


Figure 5-5 – Locations of MMCVP Project Equipment on NCSU Campus in Raleigh, NC

Source: [NCDOT Multimodal Connected Vehicle Pilot]

Existing TSP System: EMTRAC Cloud-Based TSP System

Location: GoRaleigh Route 15 (New Bern Avenue)
Description: The TSP system deployed along New Bern Avenue at 16 intersections is a cloud-based approach to TSP operations from the City's TSP vendor known as EMTRAC. The following are key parts of the system:

1. The existing AVL hardware on City of Raleigh buses is hosted on a small on-board PC computer, and this collects data on vehicle location, bus route, vehicle heading, and other variables and sends the data (at a frequency of at least once every 1-2 seconds) to a TSP software application from EMTRAC that is installed on the AVL hardware inside the transit vehicle. This integration required an Application Programming Interface (API) to be created by the AVL vendor to facilitate data transfer with the TSP application that was installed on the AVL hardware that is hosted on the small PC computer. Licensing fees for the number of vehicles on which the integration was performed are paid by the City of Raleigh to enable this integration.
2. The AVL hardware and PC computer is connected to a cellular modem that sends data from the on-board TSP application to a cloud-based TSP software from EMTRAC that processes the data to determine when buses should receive TSP at intersections on the corridor. The logic within the cloud-based TSP software allows for TSP to be requested when buses are behind schedule by at least one minute, though this is configurable by Raleigh staff. Virtual zones are also defined in the cloud-based TSP software so that TSP calls are made at an appropriate distance from the intersection.
3. The cloud-based TSP software communicates a TSP request through a server at the Raleigh's traffic management center to the appropriate traffic signal controller where TSP is being

requested. Fiber-optic cable connects Raleigh's Traffic Management Center (TMC) with the signal controllers on the corridor to enable TSP requests to signal controllers. The TSP request is made using an NTCIP 1202 standard, which is how the traffic signal controllers are configured to enable TSP operations.

The City of Raleigh has noted that while funding is secured for this approach along the New Bern Avenue corridor, the City of Raleigh would like to apply this approach to future BRT corridors in the southern and western areas of Raleigh. Additional funding has yet to be identified to support the expansion of the cloud-based TSP approach to those corridors.

This approach also requires the integration of the AVL system with an on-board TSP application from the TSP vendor through a custom API created by the AVL vendor. While this approach requires no new hardware to be installed on buses or in the field to enable TSP operations, Raleigh TMC staff have noted that licensing fees are being paid for the number of transit vehicles that have this integration completed. Additional license fees are paid to the TSP vendor for the use of the cloud-based TSP software on the corridor that can provide a real-time view of TSP operations and also provide performance measures on TSP operations. Refer to Figure 5-6 for a corridor view of the EMTRAC TSP system through the cloud-based software for the system.

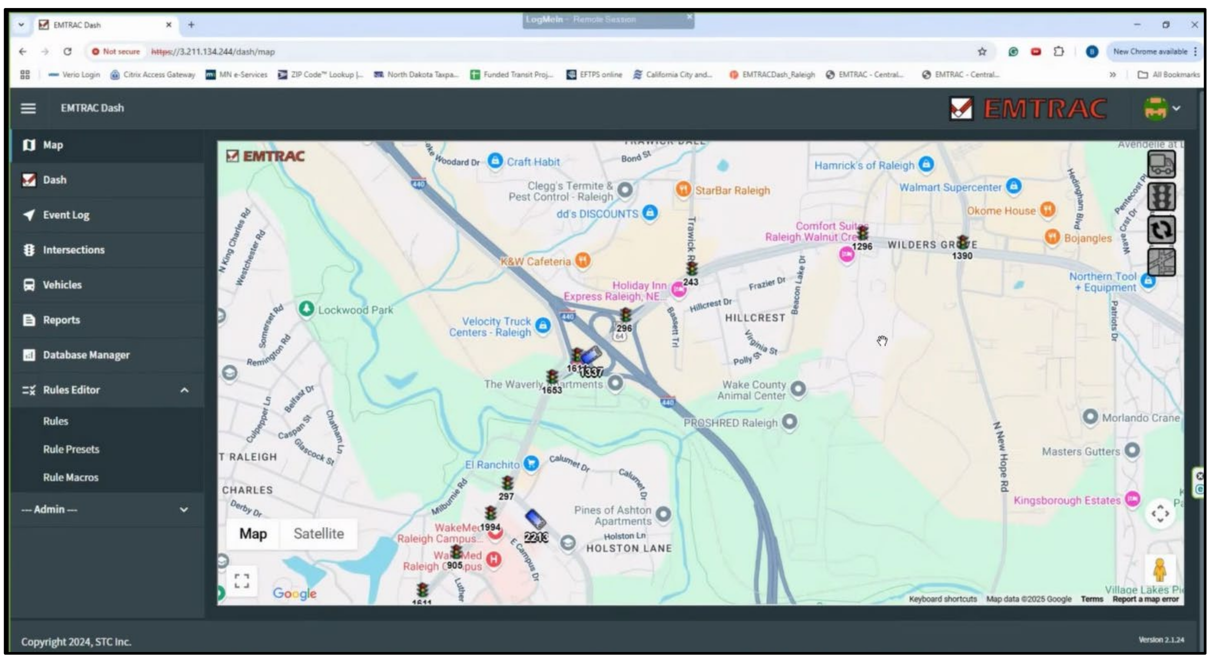


Figure 5-6 – Corridor View of EMTRAC TSP System along New Bern Avenue

The EMTRAC cloud TSP system has been implemented at 16 traffic signal locations along New Bern Avenue, but the City of Raleigh has plans to expand BRT service to future southern and western BRT lines in the coming years as shown in Figure 5-6. Note that there is also overlap with existing intersections that are a part of the current Multimodal Connected Vehicle Pilot show in Figure 5-7.

For future BRT corridors where TSP will be implemented, station locations in relation to traffic signals should be reviewed to identify where TSP can have the greatest impact on transit performance. It is more beneficial to have transit stations on the far side of a traffic signal so that it can stop to allow passengers to board and alight from buses after it has passed through the traffic signal. Mid-block station locations are also ideal locations given that buses are not stopped near a traffic signal waiting for passengers to board and alight during the time when it could be using an extended green time on a TSP request to travel through the intersection.

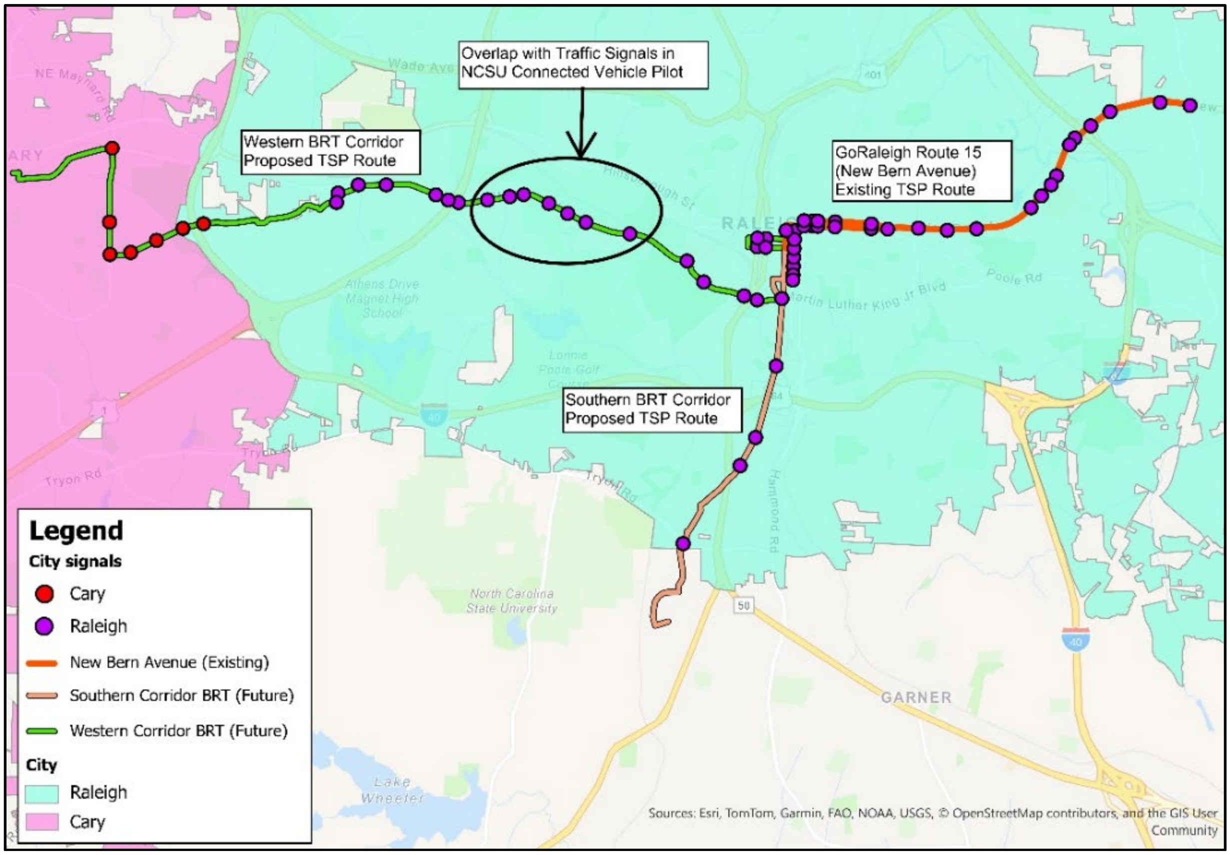


Figure 5-7 – Deployment of EMTRAC Cloud-Based System for Existing and Proposed TSP Routes

Planned TSP System: North-South Bus Rapid Transit (NSBRT) Corridor

Locations: Chapel Hill (State Route 86 / MLK Jr. Blvd.)
Description: The NSBRT project is planning for traffic signal system upgrades that will be needed to enable TSP system operations along the corridor. The desired technology for TSP operations will be decided upon by the project team and Town of Chapel Hill during the design / construction phase of the project. It is anticipated that BRT operations would commence in 2029 on the corridor from the Eubanks Park-and-Ride lot on the north side to the Southern Village Park-and-Ride lot on the south end.

Noted Challenges

One challenge to accomplishing the vision of transit vehicles benefiting from TSP across various jurisdictions, regardless of transit agency or CAD/AVL system, is the presence of multiple different TSP system vendors and approaches taken in the region. While there are available standards that have been developed to facilitate interoperability among TSP vendors, the acceptance of these standards by industry vendors is not widespread. TSP vendors often prefer their established method of communications for sending TSP, which is often a proprietary solution that would not be operable with vehicle or intersection TSP equipment from other vendors.

One available standard to guide TSP operations on traffic signal controllers, and this is referred to as NTCIP 1211[1], which is part of the National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) family of standards[2]. The purpose of NTCIP standards is to enable interoperability between hardware and software produced from different vendors of that equipment. NTCIP 1211 is one of those standards that define how messages can be communicated to traffic signal controllers to enable TSP operations. The use of this standard could help to enable future TSP interoperability of buses making TSP requests to signal controllers in multiple jurisdictions.

The MMCVP project on the NCSU campus in the City of Raleigh includes signal controllers that are providing for TSP operations by following an NTCIP 1211 standard on the controller. The MMCVP project is also using a separate standard defined by the Society of Automotive Engineers (SAE) known as an SAE J2735 standard that defines how On-Board Units (OBUs) communicate various types of information with Roadside Units (RSUs). TSP requests are only communicated using the SAE J2735 standard when the AVL system on NCSU buses detects the bus to be behind its posted schedule by more than 4 minutes. TSP requests conforming to an NTCIP 1211 standard are then translated into NTCIP 1211 by the RSU at the intersections on the NCSU campus and sent down to the signal controller that uses NTCIP 1211 to manage the TSP request.

Multiple different signal controller software manufacturers and central software systems are also in place throughout the region. The cities of Raleigh and Durham and towns of Cary and Chapel Hill manage and operate traffic signals within their jurisdictional boundaries, though most of the signals are owned by the NCDOT. A summary of these software details gathered from the NCDOT during an interview on the project is provided in Table 5-2 below:

Table 5-2: Summary of Signal Controllers and Central Software in Triangle Region

Jurisdictions	Traffic Signal Controller Hardware / Firmware	Central Office Traffic Software	Notes on NTCIP 1211 Compliance for Region
Durham / Cary	Econolite ASC/3 Signal Controller with ASC/3 firmware	Econolite Centracs and Applied Information	Would need to investigate the potential for upgrading signal controllers to be capable of TSP under the NTCIP 1211 standard
Raleigh	Yunex Traffic signal controllers with SEPAC firmware, operating on Linux platform	Tactics central software	Use of NTCIP 1211 for TSP is being tested on NCSU campus for MMCVP project.
Chapel Hill	Econolite ASC/3 Signal Controller with mix of ASC/3 and Oasis firmware	Econolite Centracs	Currently not capable with NTCIP 1211. Controllers along the planned NSBRT line will be updated with that project with new central software, and new controllers will be capable of NTCIP 1211

[1] NTCIP 1211 standard available at: https://www.ntcip.org/file/2018/11/NTCIP1211v02A-SE03.docx.
[2] Standards available at: https://www.ntcip.org/document-numbers-and-status/.

Opportunities for Innovation / Collaboration

From 2024 through 2029, the NCDOT will make a statewide upgrade of approximately 6,000 traffic signal controllers that it operates and maintains on its own with new signal controllers running MaxTime software. These controller upgrades in the field will allow the NCDOT to remotely manage and communicate with traffic signals from a new traffic central software known as Kinetic Signals. For signal controllers owned by the NCDOT, but operated and maintained by a municipality, the NCDOT has noted a number of these controllers could also be upgraded to a pre-approved signal controller with MaxTime software under the current statewide controller upgrade project.

From an interview with the NCDOT for this project, a few potential opportunities were discussed in relation to future TSP system operations. These are noted below:

1. A potential opportunity may exist for a type of centralized TSP deployment if agencies in the region were interested in an integration of their CAD-AVL system with the Kinetic Signals traffic management software. This would only be possible in locations where MaxTime software is operational on signal controllers in the field. NCDOT has also noted that they would only want to perform one CAD-AVL software integration with Kinetic Signals to reduce the amount of maintenance and updates that may be needed to the software over time. In the Triangle region, traffic signal locations would be those outside of Raleigh, Cary, Durham, Apex, and Morrisville, and Chapel Hill.

2. There may be an opportunity for the Town of Chapel Hill to collaborate with the larger NCDOT signal controller upgrade project during the construction phase of the NSBRT project. This will need to be further investigated with the NCDOT and with the Town of Chapel Hill prior to construction efforts on the corridor.

Another potential opportunity for TSP operations is the potential integration of Swiftly as a service planning software with future cloud-based TSP systems. Swiftly has noted that they can use GPS coordinates sent from buses at a high frequency (once every 1-3 seconds) in order to make an accurate determination of where buses are in relation to their posted schedule along the route. This will help identify when buses are behind schedule by pre-determined threshold in Swiftly, which can be used to send TSP requests to cloud-based TSP systems in operation along a route.

Swiftly has integrated with other cloud-based TSP vendors to send TSP requests to cloud-based TSP software vendors when buses meet a behind schedule adherence threshold defined in Swiftly by X minutes or more. A potential future integration of Swiftly with cloud-based TSP systems provides an opportunity for TSP interoperability with other transit partners that utilize Swiftly.

Case Study: Regional Transportation Authority Interoperable TSP System

To reduce bus delays at traffic signals and improve bus service reliability, the Regional Transportation Authority (RTA) of Chicago, IL designed a regional program for an interoperable TSP system across the different transit and highway jurisdictions in Chicago and its suburbs.[3] The

[3] https://rtams.org/sites/default/files/digital_documents/Evaluation%20Report%20for%20the%20Regional%20Transit%20Signal%20Priority%20Implementation%20Program%20%28RTSPIP%29.pdf

program is known as the Regional Transit Signal Priority Implementation Program (RTSPIP) and involved the Chicago Transit Authority (CTA) and Pace Suburban Bus transit agencies.

The goal of the program was to develop and implement a regionally interoperable TSP system that works for both CTA and Pace buses traveling on roadways maintained by the Chicago Department of Transportation (CDOT), the Illinois Department of Transportation (IDOT), and other local DOT's in northeastern Illinois. Program objectives include using existing bus and roadside equipment to the extent possible, as well as utilizing off-the-shelf hardware for bus-to-intersection communication.

The agencies followed a Systems Engineering approach that is recommended by FHWA and FTA beginning in 2013 to develop regional TSP standards and implementation guidelines that have been utilized to guide TSP deployment on multiple corridors throughout the region. This involved developing the following documents:

- <u>Concept of Operations</u> – Describes how a regionally interoperable TSP system will function throughout the region and includes a high-level operational description of the TSP system
- <u>Technical System Requirements</u> – Defines what the TSP system will do and how its subsystems will function under the program
- <u>Regional TSP Standards and Implementation Guidelines</u> – Standards included use of a Regional TSP Message Set and use of the 5.0 GHz frequency and 802.11n Wi-Fi communications protocols between buses and intersections to enable interoperability.
- <u>Verification Plan</u> – Provides guidance on the TSP system will be tested for compliance with the Regional TSP Standards and Implementation Guidelines.

The CTA started design engineering activities in 2014 and 2015, which included new Advanced Traffic Controllers (ATC's) and wayside communication equipment to facilitate vehicle-to-intersection communications. The CTA also worked with their AVL system to update the on-board software on the buses and at the intersections to utilize the Regional TSP Message Set. Pace Suburban Bus separately worked with a consultant team beginning in 2015 to manage TSP systems integration and design engineering services for wayside equipment along Pace corridors and also engaged their AVL system vendor to modify the existing on-board equipment to accommodate the Regional TSP Message Set.

Proof-of-concept testing began in 2018 for one corridor that included transit service from both Pace and the CTA, as well as signal controllers managed by multiple DOT's, to test the interoperability of the Regional TSP Message Set in the region. The RTA assisted with baseline data collection and analysis for performance measures before and after TSP system installation along multiple other corridors in the region.

The following are lessons learned on the project:

- While the creation of a Regional TSP Message Set for vehicle-to-intersection communications allowed for regional interoperability to occur between Pace and the CTA, this was a new approach for AVL system vendors and traffic signal controller vendors. Testing required the creation of virtual testing tools to demonstrate compliance with the message set in a bench test environment, prior to field testing, which required additional time and resources from agencies and vendors. Agencies should consider other available TSP message sets through off-the-shelf hardware, such as CV2X hardware.
- Systems Engineering documentation laid the groundwork for program requirements to be followed by transit agencies during design engineering and implementation stages. This

was helpful to define the Regional TSP Message Set and gather buy-in from regional transit and traffic agencies on the interoperable TSP project.

- Developing a regionally interoperable TSP system based on standards that could be met by multiple types of vendors took longer to develop than other approaches that might have relied upon vendor-provided, off-the-shelf TSP systems. Agencies may want to consider working with existing TSP vendors that may be able to implement on a faster timeline versus developing a standards-based approach that TSP vendors will need to adapt to over time.

Recommendations for TSP in Region

Given the existing cloud-based approaches from multiple TSP systems in the region and potential for use of available standards to guide TSP operations, the following recommendations can be followed to enable the future interoperability of TSP systems across the region.

Recommendation #1: Include NTCIP 1211 Standard in Future TSP Deployments in Region

The NTCIP 1211 standard noted earlier in this document contains the technical details for how traffic signal controllers can manage and provide TSP requests. The use of this standard in future TSP deployments in the Triangle region can establish a level of consistency in how signal controllers from different manufacturers manage TSP requests within signal controllers.

The use of NTCIP 1211 on existing signal controllers in City of Raleigh is being tested as part of the NCDOT MMCVP pilot project. An evaluation of the project will be performed by the NCSU ITRE and is expected to be completed in summer / fall of 2026. Lessons learned from the project can be reviewed to determine if there were any issues in TSP operations on signal controllers with the NTCIP 1211 standard.

Other traffic agencies in the region will need to review whether NTCIP 1211 can be implemented on their existing traffic signal controllers to support TSP operations. Upgrades to some traffic signal controllers may be necessary if transit agencies require their TSP system vendor to utilize NTCIP 1211 as a standard for how signal controllers should provide for TSP operations. Gathering support from traffic agencies to implement NTCIP 1211 can be an early step in the planning process for expanding this approach to traffic signals throughout the region.

Recommendation #2: Establish Stakeholder Contact Listing for Future TSP Working Group

In contacting traffic agencies to discuss NTCIP 1211, a list of TSP agency stakeholders can be created to that could include traffic engineers and emergency management staff that operate EVP at traffic signals in the region. This stakeholder contact list can support future efforts to implement TSP across additional corridors in the region.

A TSP Working Group can also be established in the region that could meet on a recurring basis to support interagency collaboration on the recommendations included within this plan. Transit agency staff can review meetings that can occur with traffic agency staff in discussing how TSP operations are progressing in the region, and how the recommended approach for NTCIP 1211 can be implemented in the region.

Members of this TSP Working Group can also join a national-level peer agency TSP Working Group that includes transit agencies that have implemented TSP systems throughout the country. The purpose of the peer agency working group is for transit agencies to learn about past TSP System deployments and current efforts with respect to TSP operations. Agencies that are using NTCIP 1211 could be consulted from this group to also gather best practices and lessons learned.

Recommendation #3: Review Connected Vehicle Approach for TSP with NCSU MMCVP Pilot Project

As an alternative to the cloud-based TSP software approach, this approach includes CV hardware on buses and at intersections to facilitate direct communications with traffic signals for TSP requests. The Connected Vehicle-to-Everything (CV2X) standard has been created to define the TSP messages that can be communicated between CV hardware on vehicle and at intersections, and this allows for the procurement of CV hardware from multiple vendors that can meet this standard.

Transit agencies in the region that may desire to follow this approach should consult with an evaluation report that will be prepared by the NCSU Institute for Transportation Research and Education (ITRE) as part of the larger MMCVP project funded by the NCDOT. This evaluation may influence the spread of CV technology to additional areas in the region, and transit agencies should consult the evaluation report for any potential lessons learned with regards to TSP operations. A timeline for an evaluation report is anticipated in summer / fall of 2026 for the project.

This Connected Vehicle approach would utilize an SAE J2735 standard for communications of TSP requests between On-Board Units (OBUs) on buses and Roadside Units (RSUs), as well as a conversion of the TSP request into an NTCIP 1211 standard format for traffic signal controllers. This is being tested under the larger MMCVP project and can be reviewed for its potential to be installed in other areas of the region.

It should also be noted that this approach requires new CV communications equipment to be installed at traffic signals and on buses, which is equipment that must be configured, maintained, and eventually replaced over time. These are considerations to be weighed in considering how best to expand TSP service in the region given existing cloud-based systems. Additional considerations with respect to CV equipment are listed below:

1. Verify that any selected vendor of CV hardware has been certified by the Omni-Air Consortium to support future interoperability with other vendors. An overall goal of the Omni-Air Consortium is to assist with the interoperability of devices as more manufacturers develop and produce more devices for CV2X deployments. A certified products listing is maintained and updated on an ongoing basis for reference by public agencies that desire to install this equipment. This listing should be reviewed by transit agencies to verify that any CV2X hardware purchased will be interoperable with other CV2X hardware in the future. Additional information can be found at: https://omniair.org/.

2. Coordinate with the transit agency AVL vendor to enable the integration of future on-board CV hardware with existing on-board AVL hardware, so that TSP requests can be made when buses are detected as being behind schedule. NCSU Wolfline buses completed this on-board integration through working with their AVL vendor (Passio Go) for the MMCVP Project.

3. Consult with the City of Raleigh traffic operations staff if CV technology is desired to be installed at other traffic signal locations in Raleigh outside of the MMCVP project area on the NCSU campus. Traffic operations staff will be able to identify any additional signal

cabinet hardware or communications infrastructure that may be needed to support TSP operations.

4. For other jurisdictions in the region where the cloud-based TSP system from the vendor AI has been installed, it is possible that Connected Vehicle hardware can be installed at those intersections to facilitate TSP operations for other transit agencies. The transit agency should consult with the jurisdiction responsible for traffic signal operations and the vendor for cloud-based TSP operations to identify any additional steps that may be needed to allow for a CV approach to co-exist with the cloud-based TSP system at those locations. It is possible that some traffic signal controllers may need to be updated in order to receive and process TSP requests using CV equipment.

Recommendation #4: Determine Potential for Existing Cloud-Based TSP Systems to Accommodate NTCIP Standard for TSP and/or SAE J2735 Standard for CV Communications

A cloud-based TSP system has been implemented by two separate vendors in the region as noted earlier in the document, with Applied Information (AI) operating in Cary, Durham, Apex, and Morrisville and EMTRAC operating in Raleigh. Given the investment in these systems and the recommendation to implement a standards-based approach for future TSP operations in the region, transit agencies should consult with their TSP vendors to identify how existing systems could be updated to accommodate the NTCIP 1211 standard for signal controllers, as well as SAE J2735 standards for communications between buses and intersections.

It is possible that hardware and software upgrades would be required to the equipment that has been installed for these existing cloud-based TSP systems. TSP system vendors will need to understand what is required to determine the feasibility of the upgrades and estimate the potential costs of those upgrades. Future meetings with transit and traffic agency responsible for maintaining these systems and the TSP vendors can occur over time to determine these potential upgrades.

Recommendation #5: Review Transit Routes and Identify Candidate Corridors for TSP Service

Given the existing use of schedule adherence as a measure to enable TSP requests by buses, transit agencies should identify transit routes that have relatively lower on-time performance metrics than others. TSP operations could help to improve these on-time performance metrics through sending TSP requests when buses are behind schedule as measured by the existing on-board AVL system. The Town of Cary has seen an initial improvement in on-time performance along their Route 5 (Kildaire Farm Road) by initiating TSP requests when behind schedule by 1 minute, and they will continue reviewing data through 2025 to determine any adjustments that may be needed.

This step of reviewing transit routes will require coordination with transit service planners to review candidate transit routes for TSP operations. Service planning staff can determine the types of AVL system data that can be collected before and after TSP implementation to help with an evaluation of TSP operations that are enabled by schedule adherence thresholds set by AVL systems.

Recommendation #6: Identify Potential Corridor for Testing of Regional TSP Interoperability

Given the vision of providing buses from multiple transit agencies the opportunity to benefit from TSP across various jurisdictions in the region, a future corridor can be identified where multiple TSP systems could provide TSP to transit agencies utilizing the recommended NTCIP and / or SAE J2735 standards from the plan.

One potential corridor could be along Western Boulevard where the current NCDOT MMCVP project is being tested currently. This corridor includes a future Raleigh BRT line (Western BRT Corridor) that would travel from Raleigh into Cary and could potentially contain the following systems for a future interoperability demonstration of TSP operations:

1. City of Raleigh may extend the use of the existing EMTRAC cloud-based TSP System to support BRT operations, and if so, BRT buses from Raleigh may need to interface with traffic signals in Cary. This would allow for Raleigh BRT buses to perform TSP operations at the identified traffic signals in Cary.
2. The Raleigh BRT buses would also be traveling through signals that are currently a part of the NCDOT MMCVP pilot project that include CV equipment being used for TSP operations with NCSU Wolfline buses. Future discussion with City of Raleigh traffic agency staff will be needed to determine how TSP could best be provided in this area of overlap.

3. GoTriangle also operates the Route 300 and Route 305 along this area of Western Boulveard and could benefit from use of either the existing EMTRAC cloud-based TSP system that communicates TSP requests to traffic signals in Raleigh or from the CV equipment installed as part of the NCDOT MMCVP pilot project.

Given the overlap of transit services in the area, this corridor could serve as a potential area of TSP interoperability testing, but would require coordination between transit and traffic agencies in the region to enable system interoperability on the corridor. The TSP Working Group proposed in the first recommendation could assist with identifying the key stakeholders that would need to be involved in working towards TSP interoperability along the proposed corridor. Figure 5-8 presents an overview of the area along Western Boulevard where a potential future interoperability test of TSP operations could be performed.

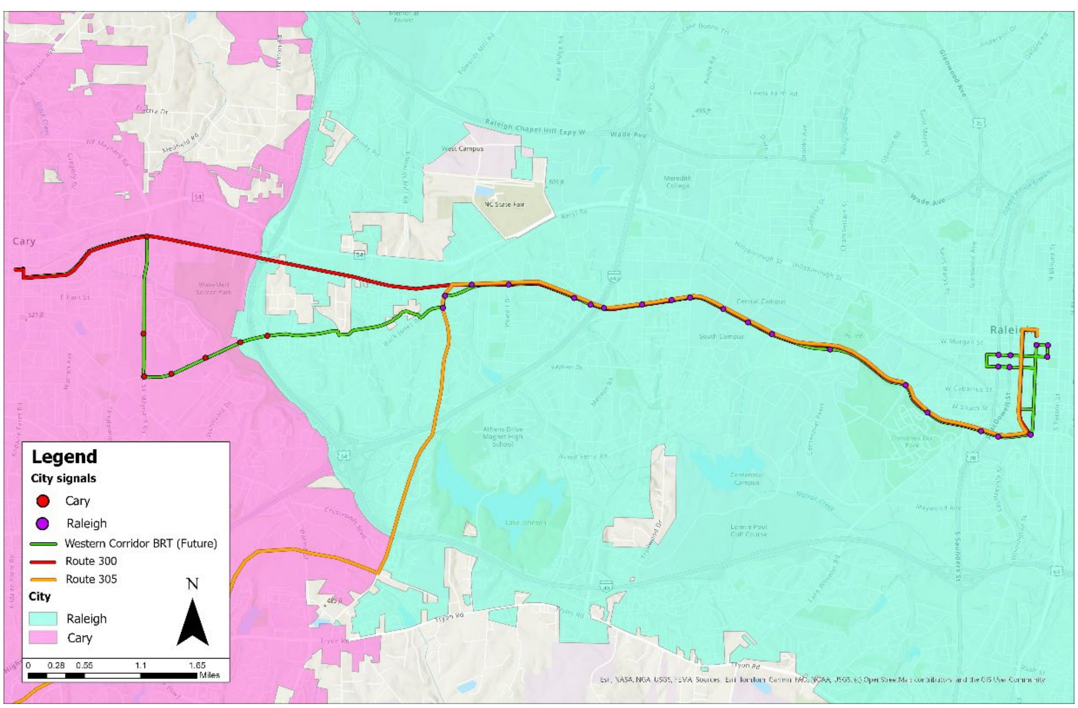


Figure 5-8 – Potential Future TSP Interoperability Test Corridor along Western Boulevard

Roadmap and Resiliency Plan for TSP in Future Years

A roadmap with phased steps for TSP implementation in the Research Triangle region is presented in Figure 5-9 that takes into consideration the recommendations provided in the prior section. The steps are proposed over five years of time but may stretch to shorter or longer periods based on progress made by transit agencies with respect to expansion of TSP operations.

The use of the NTCIP 1211 standard can support can support future interoperability of TSP system operations across multiple transit agencies and jurisdictions. A TSP Working Group will need to be developed for the region to guide discussions and meetings with transit and traffic agency staff so that the standard can be adopted and used in future TSP deployments.

Budgetary considerations are provided in Table 5-3 for transit agencies to plan for County Transit Plan funding requests if TSP projects are advanced throughout the region. Budget estimates are provided for vehicle, intersection, and other project items to be accounted for by transit agencies in future years.

Planning-level cost estimates are provided in Table 5-4 and Table 5-5 for each of the two TSP system approaches presented in Table 5-3. An estimate of buses in each agency fleet is multiplied by the vehicle cost estimate in Table 5-3. In addition, an estimated number of traffic signals along transit routes at which TSP could be provided for each agency is provided in Table 5-4 under the Connected Vehicle approach for TSP operations. This intersection count was gathered from use of ArcGIS in reviewing the number of traffic signals along transit routes for each transit agency.

Table 5-5 includes a planning-level cost estimate that accounts for the use of cloud-based TSP systems expanding from the current base in the region. Notes are placed in the far right column to indicate differences from the planning-level cost estimate presented in Table 5-4.

The planning-level cost estimates include anticipated vehicle and intersection-based cost items. Other overall project cost items are estimated, but these may vary based on the vendor providing TSP equipment for each agency. Additional cost items due to updates in Connected Vehicle equipment and cloud-based TSP systems may be identified as future TSP deployments by agencies advance into a more detailed design and deployment stage with TSP vendors. Integration costs may also be identified in future design and deployment efforts by TSP vendors in areas interoperability between TSP systems is desired.

Step 1: Include NTCIP 1211 in Plans for TSP Operations / Expansion Discuss the use of the NTCIP 1211 standard with transit and traffic agencies to identify potential upgrades that may be needed on traffic signal systems along future TSP corridors in the region. Review operation of NTCIP 1211 in Raleigh on NCSU campus.	**Step 2: Establish Stakeholder Contact Listing for Future TSP Working Group** Develop list of TSP agency stakeholders (traffic engineers emergency management staff, transit staff, etc...) that would be involved in future TSP projects. Create a TSP Working Group to meet on recurring basis to support interagency collaboration on the recommendations from the plan.	**Step 3: Review CV Approach for TSP with NCSU MMCVP Pilot Project** NCSU ITRE will evaluate the project and identify lessons learned with respect to TSP operations for NCSU at traffic signals with CV equipment. Recommendations from the report may lead to the expansion of CV equipment in the region. Evaluation of TSP operations with NTCIP 1211 standard can also be reviewed.
Years 0-1	**Years 0-1**	**Years 1-2**
Step 4: Determine if Existing Cloud-Based TSP Systems can use NTCIP 1211 Standard / SAE J2735 Standard Identify hardware and software upgrades that may be needed to existing cloud-based TSP systems that could accommodate interoperability of TSP from multiple transit agencies. Meet with existing vendors of TSP systems to understand potential approaches and costs of upgrades.	**Step 5: Review Transit Routes and Identify Candidate TSP Corridors** Identify routes with on-time performance issues that could benefit from TSP system operations. Ensure integration between AVL system and TSP system to enable schedule adherence-based TSP requests. Identify AVL system data that can be collected before and after implementation to help with TSP system evaluations.	**Step 6: Identify TSP Approach along North-South BRT Corridor** Identify technology approach to TSP along the north-south BRT corridor. Coordinate with other transit agencies on the approach to enable interoperability of TSP operations where possible on the corridor.
Years 1-2	**Years 1-2**	**Years 2-3**

<u>Step 7</u>: Identify TSP Approach along Raleigh BRT Corridors Raleigh will identify funding sources to support expansion of cloud-based TSP system along the southern and western Wake BRT corridors. The traffic department will identify any traffic signal hardware updates needed to enable TSP along corridors.	→	**<u>Step 8</u>: Identify Corridor for TSP System Interoperability Testing** Raleigh will identify funding sources to support expansion of cloud-based TSP system along the southern and western Wake BRT corridors. The traffic department will identify any traffic signal hardware updates needed to enable TSP along corridors.	→	**<u>Step 9</u>: Coordinate with Signal System Expansion in Region** Traffic signal operations in Holly Springs and Fuquay-Varina to be expanded to allow for Emergency Vehicle Preemption. NCDOT will evaluate location of signal operations center in Holly Springs for monitoring of signals.
Years 3-4		**Years 4-5**		**Years 4-5**

Figure 5-9 – Roadmap of Implementation Steps for Transit Agencies for Regional TSP Operations

Table 5-3: Budgetary Planning Recommendations for Transit Agency Consideration

TSP System Approaches	Vehicle Budget Items	Intersection Budget Items	Other TSP Project Items
Use of Connected Vehicle (CV) Approach for TSP Operations	**$5,000** per OnBoard Unit (OBU) for purchase, installation, and integration with existing AVL hardware on vehicles	**$5,000** per Roadside Unit (RSU) for purchase, installation, and setup at traffic signal	**$30,000** for communications backhaul from intersections to central software. **$25,000** per year for vendor PM costs, warranty, and central software access for monitoring
Use of Existing Cloud-Based TSP Software	**$5,000** per OnBoard Unit (OBU) for purchase, installation, and integration with existing AVL hardware on vehicles	If expanding to signals outside of current deployment, **$10,000** for new equipment and integration with traffic signals	**$25,000** per year for vendor PM costs, warranty, and central software access for monitoring

Table 5-4: Planning-Level Cost Estimate for Use of Connected Vehicle (CV) Approach for TSP Operations							
	Buses in Fleet	**Vehicle Cost Estimate**	**Intersections on Transit Routes**	**Intersection Cost Estimate**	**Other TSP Project Items***	**Total Costs**	**Notes**
GoTriangle	74	$5,000	203	$5,000	$55,000	$1,440,000	Assumes 7 intersections on Western Blvd. with CV RSUs
GoCary	15	$5,000	78	$5,000	$55,000	$545,000	
GoDurham	63	$5,000	291	$5,000	$55,000	$1,825,000	
GoRaleigh	137	$5,000	506	$5,000	$55,000	$3,270,000	Assumes 7 intersections on Western Blvd. with CV RSUs
Chapel Hill Transit	91	$5,000	87	$5,000	$55,000	$945,000	
						$8,025,000	

* See notes in Table 5-3 above.

Table 5-5: Planning-Level Cost Estimate for Use of Existing Cloud-Based TSP Software							
	Buses in Fleet	**Vehicle Cost Estimate**	**Intersections on Transit Routes**	**Intersection Cost Estimate**	**Other TSP Project Items***	**Total Costs**	**Notes**
GoTriangle	74	$5,000	140	$10,000	$25,000	$1,795,000	Intersection total accounts for signals in the Durham and Cary areas already equipped for TSP operations.
GoCary	15	$5,000	0	$10,000	$25,000	$100,000	5 buses already using TSP. Intersections in Cary ready for cloud-based TSP.
GoDurham	63	$5,000	0	$10,000	$25,000	$340,000	5 buses already using TSP. Intersections in Durham ready for cloud-based TSP.
GoRaleigh	137	$5,000	497	$10,000	$25,000	$5,680,000	Intersection total accounts for 16 signals on New Bern with cloud-based TSP currently
Chapel Hill Transit	91	$5,000	87	$10,000	$25,000	$1,350,000	
						$9,265,000	

* See notes in Table 5-3 above.