Attach To Contract Document

New York City Department of Transportation
Traffic Operations

REQUEST FOR PROPOSALS

TO

DEVELOP, DEPLOY, SUPPORT AND MAINTAIN EXISTING AND FUTURE CITYWIDE TRANSIT SIGNAL PRIORITY (TSP)

EPIN: 84126P0001
P.I.N.: 84125MBTR709

Addendum No. 6

October 21, 2026

This Addendum Is Hereby Made Part of the Contract Documents

Attached please find:

Addendum No. 6

1. **Notice to Proposers**
2. **Written answers to written questions received prior to the expiration of the 10/13/26 by 5:00 pm deadline for the submission of questions.**
3. **Transit Signal Priority Systems Engineering Analysis Report**

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NOTICE TO PROPOSERS

Except as otherwise stated below and by any previous and subsequent Addenda, the above-referenced solicitation remains unchanged. Furthermore, this Addendum is hereby made part of the contract documents.

The proposal due date/time is now **extended** from 10/30/26 by 2:00 pm **to 11/5/26 by 2:00 pm.**

This Addendum includes answers to all but three (3) written questions received by the expiration of the cut-off date/time for submission of questions, 10/13/26 by 5:00 pm. Answers to question numbers 9, 13 and 39 are still under consideration. Answers to those questions will be provided in a future Addendum.

Questions received by expiration of the question submission deadline of 10/13/26 by 5:00 PM

Q1. Corridor Expansion – Please confirm the anticipated number of new corridors to be deployed during the four year contract term.

A1. Regardless of the number of corridors, DOT plan is to deploy/re-evaluate up to 3,000 **intersections** during the 4 years project period.

Q2. System Integration – Should vendors assume responsibility for upgrading existing ITS components, or only for new deployments?

A2. There are no hardware ITS Components included in this procurement. All work is software related, programming and configuration.

Q3. Support Model – Does NYC DOT expect 24/7 support coverage, or business hours maintenance with escalation protocols?

A3. Staff monitoring and support is expected only during business hours(8am- 5PM). However automated system alerts for major failures shall be in place.

Q4. Budget Guidance – Is there an estimated funding allocation for this engagement, or should vendors propose fully open pricing models?

A4. Refer to Section III of the RFP. DOT will not disclose the maximum available funding for this project.

Q5. Knowledge Transfer – Should vendors plan formal training sessions for DOT staff, or is documentation sufficient?

A5. Formal training for DOT staff is expected in case of any new system deployment.

Q6. Pre Proposal Conference – Will attendance at the Sept 28 Microsoft Teams session be mandatory for eligibility?

A6. The conference was rescheduled to 10/9/26; attendance was not mandatory.

Q7. Submission Compliance – Please confirm if proposals submitted via PASSPort only are valid, or if email submission is also acceptable

A7. Submission through PASSPort is required. No other means of submission is acceptable.

Q8. Please specify if there are bond requirements for this solicitation.

A8. There are no bond requirements.

Q9. With reference to the Cloud Agreement: Certain cyber coverage provisions requested in the agreement are not available in the commercial insurance market, specifically:

Coverage for intentional, dishonest, fraudulent, malicious, or criminal acts.

Coverage for theft of a customer's money or securities resulting from a cyber event. Commercial cyber policies generally cover loss of data rather than direct theft of funds.

Commercial cyber policies generally cover loss of data rather than direct theft of funds. Furthermore, this project does not involve the contractor having access to customer funds. Is coverage for theft of data rather than money acceptable.

A.9 To be answered in a future addendum.

Q10. With reference to 84126P0001_Cost Form_revised_LOCKED: This is a quals based selection (QBS) according to the RFP. There is no defined scope at this time. What should the entered hours be based on?

A10 The Scope of work is defined in the RFP document under Section II(C). The hours per title should be based on your estimate of how many hours will be worked under that title by the Prime and each of its subconsultants for the duration of the 4 year term of the contract. As per the instructions tab, hours worked per title by the Prime contractor should be entered on the Prime tab in column C ; hours worked per title by subcontractor(s) should be entered on the subconsultant(s) tab in column C.

Q11. May the same individual serve as both the Project Manager and the Account Representative? Please clarify whether the Account Representative is intended to serve primarily as an escalation contact or as NYCDOT's main point of contact. The RFP appears to identify the Account Representative as the primary point of contact however, our proposed Project Manager would lead the day-to-day administration and operations of the contract.

A11 The same individual may serve as both Project Manager and Account Representative. The Account Representative will be the vendor's main point of contact with NYCDOT. The vendor should designate a separate individual as Account Representative unless they intend for the Project Manager to perform the duties/role of Account Representative as well. If that is the case, the vendor should make clear in their submission that the Project Manager will also be acting as, and performing the duties of, Account Representative.

Q12. We cannot confirm from any of the RFP documents if federal funds will be used for this project. Can you confirm if this project will use federal funding?

A12. That the RFP includes Section II(D) ("Disadvantaged Business Enterprise in Federal Aid Projects") and the Affirmations Section of the Technical Envelope Questionnaire of the RFx includes a Federal Contract Provisions and Requirements section is indicative that the contract will be at least partially funded by federal (FHWA) funds.

Q13. To comply with the Community Hiring requirements, contractors must utilize Referral Sources and make documented best efforts to recruit eligible Community Hires. Please

confirm whether NYCDOT will provide contractors with access to designated Referral Sources, candidate referral programs, or workforce-development organizations that can identify eligible and qualified applicants. Additionally, please clarify whether a contractor's good-faith use of such Referral Sources will be considered evidence of compliance with the best-efforts requirement when qualified candidates are unavailable for a particular position.

A13. To be answered in a future addendum.

Q14. How does this RFP interact with the New York City Transit Intelligent Signal Priority (ITSP) procurement that is currently underway. Please elaborate the expected interaction between the two systems.

A14. NYCDOT and MTA center to center communication shall remain or be enhanced as needed.

Q15. With reference to RFP Section II(C)(1.2) at page 9: The RFP says that periodic operation reports should be issued (daily-weekly-monthly) in MSExcel format. Would you accept these reports in Power BI format?

A15. We usually ask for MS Excell format. However future implementation of Power BI format can be discussed after the award.

Q16. With reference to RFP Sections II(C)(1.3 and 3.1) at pages 9 and 16: Does NYCDOT have a preferred simulation modeling tool (i.e., VISSIM, Aimsum?

A16. DOT currently uses Synchro and Aimsum.

Q17. With reference to RFP Sections II(C)(1.3 and 3.1) at pages 9 and 16: Does NYCDOT want simulation modeling of all corridors listed in Exhibit 2?

A17. The consultant will utilize traffic simulation model to test the performance of up to 10% of the planned 3000 intersections on as needed bases.

Q18. What existing data can be provided for these corridors for evaluation and simulation (i.e., INRIX, traffic counts, travel times)?

A18. Currently NYCDOT can provide travel time data; in the future other traffic data may be shared.

Q19. Are there third-party big data providers that the agency prefers not to use?

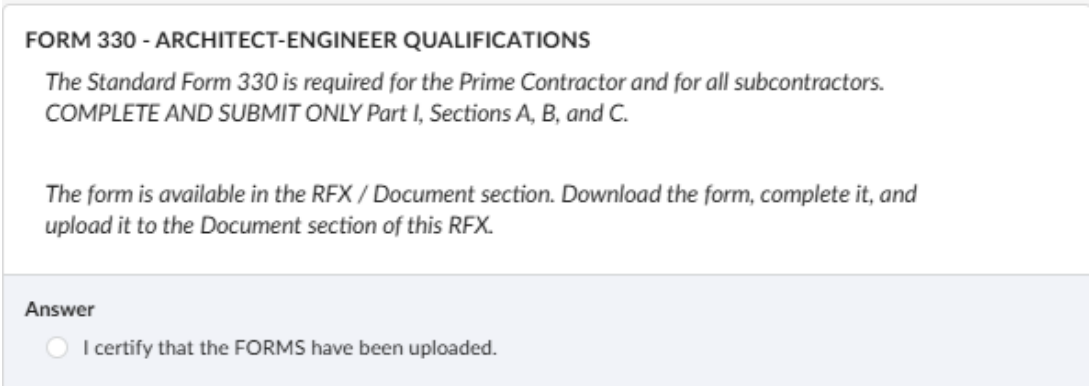
A.19. No.

Q20. Are graphics permitted in the proposal: charts (other than the org chart), illustrations, flow charts, diagrams, etc.?

A20. Yes.

Q21. Please confirm which sections of the SF 330 form must be completed [Refer to the Affirmations Section of the Technical Envelope RFx Questionnaire, specifically, specifically at Form 330 – Architect – Engineer Qualifications]

A21. Note what is stated at Affirmations Section of the Technical Envelope RFx Questionnaire, specifically at Form 330 – Architect – Engineer Qualifications (per screenshot below):



Q22. The DBE goal is 0%, but DBE forms are still required. Please confirm which forms are needed for/from DBE firms for submittal. [RFP Section II(D) at page 17 and the Affirmations Section of the Technical Envelope RFx Questionnaire, specifically, at Disadvantaged Business Enterprises in Federal Aid Projects clearly indicates that only the DBE Utilization Goal Form must be completed and submitted.]

A22. RFP Section II(D) at page 17 and the Affirmations Section of the Technical Envelope RFx Questionnaire, specifically, at Disadvantaged Business Enterprises in Federal Aid Projects, clearly indicate that the DBE Utilization Goal Form must be completed and submitted. RFP Section II(G) at page 17 ("Federal Contract Provisions and Requirements") indicates which "Federal Disclosures and Certificates" must be submitted. Refer also to the Document Submission Setup tab of the Questionnaire.

Q23. Will existing calibrated models be provided, or must the contractor develop them?

A23. No existing calibrated Models will be provided.

Q24. Would NYCDOT consider extending the due date for the proposal? [DOT has already extended the extend the proposal due date]

A24. The proposal due date may be further extended if circumstances warrant further extensions.

Q25. Do you have a page limit on any of the proposal sections?

A25. No.

Q26. With reference to RFP Section II(C)(3) at page 15 (Task 3), where the RFP states "Enhancements to existing communication systems": would this include potential support of procurement of new equipment and/or design and construction support of the communication system? Or primarily development of the plan on what is needed and how to add these?

A26. No procurement of equipment is involved. The Enhancement to existing communication system would include technical analysis of the existing communication, providing plans, and recommendation for improvement.

Q27. With reference to Task 1.1, RFP pages 7 and 8: Would the agency allow access for the consultant to their testing facility (https://ogs.ny.gov/dot-central-testing-laboratory) to test controllers in the cabinets and various versions of the controller?

A27. The referenced testing facility belongs to NY State DOT not the NYC DOT. Upon NYCDOT approval, any required testing shall be done by accessing NYCDOT testing environment remotely, or the consultant may choose to arrange their own testing environment.

Q28. With reference to RFP at page 5, Does the agency have a minimum number of key personnel they would like to see?

A28. No.

Q29. Performance measures: What performance metrics and acceptance criteria will be used to evaluate successful TSP deployment and system improvements? Are there established targets for travel-time savings, reliability, TSP request success rate, or impacts on general traffic?

A29. Performance measures are bus travel-time Improvement and number of successfully implemented TSP requests.

Q30. With reference to RFP Section II(C)(3) Implementation of Transition to Adaptive TSP Operation: Algorithm responsibilities: Will the selected consultant be responsible for developing and implementing new adaptive signal-control algorithms, or primarily for researching, recommending, testing, and coordinating modifications developed by NYCDOT's existing TCS provider?

A30. No new development of Adaptive TSP Algorithm is included. If requested, The Vendor, will be responsible for supporting DOT to migrate the existing TSP Intersections Into the new Adaptive TSP system. Full details are under Section II, Item 3 in the RFP Document.

Q31. With reference to RFP Section II(C)(3) Implementation of Transition to Adaptive TSP Operation: Adaptive TSP scope: Is the transition to Adaptive TSP anticipated to be implemented during the four-year contract, or is it an optional service to be authorized

separately? Should proposers include the associated development, integration, testing, and deployment effort in their base proposal?

A31. For any new deployment please refer to Section II , Item 3 Implementation of Transition to Adaptive TSP operation; however, the selected consultant shall maintain any existing deployment of Adaptive TSP as directed by NYCDOT.

Q32. With reference to RFP Section II(C)(1.2) TSP System Operation Monitoring and Management: What is the anticipated level of field support by the selected consultant to diagnose and assist NYCDOT in the replacement of defective hardware?

A32. The consultant is not responsible for any field Hardware replacement.

Q33. What NMS does NYCDOT currently use?

A33 NYCDOT Uses " WhatsUp Gold."

Q34. Does the NMS monitor the server applications?

A34. It does not monitor applications but provides an ability to monitor accessibility of TCP/sockets (used by application) or status of a Windows Service (if an Application runs as a Windows Service).

Q35. What reports does the central TSP system generate? Do the reports provide enough detail per intersection and per bus to show anomalies?

A35 The central TSP system provides intersection-level operational and status information through the Traffic Control System (TCS), including signal timing, phase status, communication status, failures, alarms, and TSP configuration. The System Log Viewer provides timestamped event logs showing TSP requests, controller responses, request clearances, vehicle and route identifiers, strategy numbers, and signal-control mode changes. These details provide useful visibility into anomalies at individual intersections and allow TSP events to be traced to specific buses and routes.

Q36. Will the DOT be providing the current JHK system documentation to the selected consultant?

A36. Transit Signal Priority Systems Engineering Analysis Report is attached to this Addendum The scope of this contract is only to address TSP operation , not to change/replace existing TCS System.

Q37. Can the current documentation be provided now so it can be evaluated and used to ascertain level of effort for the proposal response?

A37. Refer to A36 above.

Q38. Would NYCDOT consider extending the proposal submission deadline?

A38. Refer to A24 above.

Q39. Are remote/international vendors or subcontract implementation partners eligible to participate if they can support software development, dashboards, data workflows, integrations, monitoring/reporting tools, documentation, and ongoing technical support remotely?

A39. To be answered in a future addendum.

New York City Sub-Regional ITS Architecture
Transit Signal Priority

Project Systems Engineering Analysis Report Final Report

TO-16: Transit Signal Priority Systems Engineering
Services Pin: 84110MBTR915

May 2026

Prepared for

New York City Department of Transportation

In Association with

Prepared by

JHK Engineering, P.C.

New York City Sub-Regional ITS Architecture
Transit Signal Priority

Project Systems Engineering Analysis Report Final Report

TO-16: Transit Signal Priority Systems Engineering
Services Pin: 84115MBTR915

Prepared for

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New York City Department of Transportation

In Association with

Metropolitan Transportation Authority

NYSDOT

U.S. Department of Transportation Federal Highway Administration

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May 2026

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1. Introduction

This document is an update to the "Transit Signal Priority Project Systems Engineering Analysis Report (TSP PSEAR)" dated May 2022. This update includes NYC central Traffic Signal Priority (TSP) developments since May 2022 , including alignment with the 2022 update of the NYC Sub-regional Intelligent Transportation System (ITS) Architecture (NYCSRA).

The NYCSRA 2022 update, in turn, incorporates dataflows recommended in the 2022 TSP PSEAR relevant service packages.

This report is written for systems engineering staff responsible for overseeing ITS programs. It includes information for constructing and deploying the system which provides the foundation for system operation and future configuration management. The project introduces three new service packages to NYCSRA and makes use of two existing service packages implemented by previous ITS projects:

- TM03 - Traffic Signal Control (Existing)
- PT01 - Transit Vehicle Tracking (Existing)- NYCSRA 2022 Updated
- PT09 - Transit Signal Priority (New and now part of NYCSRA 2022 update)
- DM01: ITS Data Warehouse (New)
- DM02: Performance Monitoring (New)

These service packages are consistent with the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) Version 9.3.

The New York City Sub-region consists of the geographic area encompassing New York City's boroughs of Manhattan, the Bronx, Brooklyn, Queens, and Staten Island. These five boroughs (i.e., counties) are at the center of the New York – New Jersey – Connecticut Region that covers 29 counties. Sub-region stakeholders consist of over 75 individual organizations and groups of providers and users.

The NYC central TSP project's intent is to increase the on-time schedule performance of the Metropolitan Transportation Authority's (MTA) 5800+ buses over their 2,952 miles of service routes in all five boroughs and improve the overall intersection traffic operation (delays, speed, air quality, etc.) specifically during the peak commute hours. This concept represents multi-modal management of the corridors and is consistent with the Active Transportation and Demand Management (ATDM) and Integrated Corridor Management (ICM) operational strategies. The project integrates the transit agency's bus operations with the transportation department's signal operations. The project provides a dynamic means to improve the transit operations and the corridor's capacity in terms of people throughput.

This report addresses the requirements specified in the Federal Highway Administration's (FHWA's) Code of Federal Regulations (CFR) 940 and the Federal Transit Administration's (FTA's) policy "National ITS Architecture Policy on Transit Projects." These documents are commonly referred to as FHWA Rule 940 and FTA Final Policy respectively. The report is structured in conformance with accepted New York State Department of Transportation (NYSDOT) practices. An additional chapter is included to analyze the project's risks in accordance with the FTA Final Policy.

This project implemented the capabilities needed to expand the Transit Signal Priority (TSP) system across New York City by deploying the TSP application on MTA buses' multipurpose

onboard computing platform. This architecture increased flexibility in route configuration and reduced onboard system complexity because the TSP application could be installed and updated wirelessly over the air.

Future projects could focus on enhanced algorithms that account for transit vehicle occupancy and resolve competing priority requests among multiple transit vehicles and routes. These enhancements may be implemented as additional funding becomes available and as lessons are learned from this project.

Future projects may also build on NYCDOT's recently deployed connected vehicle infrastructure and adaptive controller deployments to expand TSP capabilities. These efforts could also support more advanced algorithms for estimating and improving transit vehicle arrival times.

Figure 1 shows the specific project ITS subsystems against the Physical View of the ARCC-IT Version 9.3. The subsystems highlighted are Transit Vehicle OBE (On-Board Equipment), Transit Management Center, Traffic Management Center, ITS Roadway Equipment, and Archived Data Systems. The communications highlighted are Wide Area Wireless, Center to Field and Center to Center.

Portions of this report are assembled from previous project documents. Each reference document is listed in the bibliography.

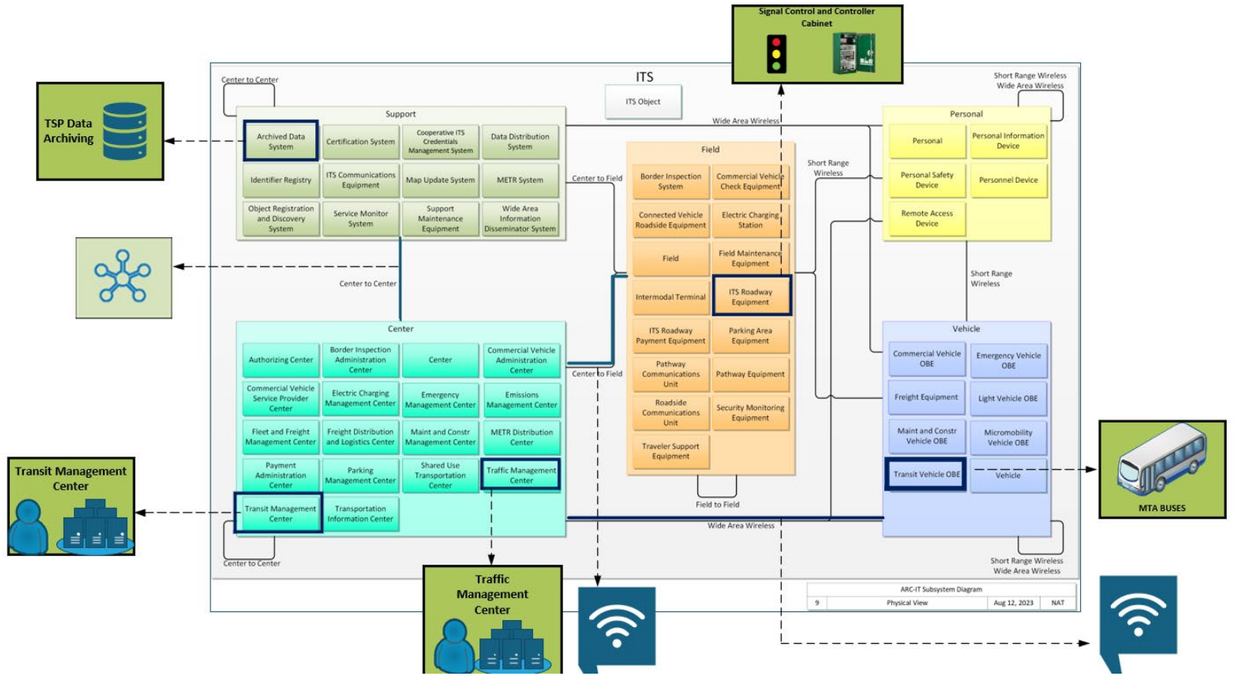


Figure 1: Portions of the ARC-IT Version 9.3 Physical View Covered by the Transit Signal Priority Project

NOTE: TSP Project subsystems and communications are highlighted.

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2. Project Systems Engineering Analysis

The following sections address each of the Rule 940 requirements. Together they provide the project's systems engineering analysis. The sections are:

2.1 Portions of the NYC Sub-regional ITS Architecture Being Implemented

2.2 Participating Agencies Roles and Responsibilities and Concept of Operations

2.3 Requirements Definitions

2.4 Analysis of Alternative System Configuration and Technology Options

2.5 Procurement Options

2.6 Applicable ITS Standards and Testing Procedures

2.7 Procedures and Resources Necessary for Operations and Management of the System

The following section addresses the project's risks in accordance with the FTA Final Policy:

2.8 Risk Analysis

2.1 Portions of the Sub-regional ITS Architecture being Implemented

The TSP project incorporates three new ITS service packages into the New York City Sub-regional ITS Architecture. The new services, known in the ARC-IT Version 9.3 as Transit Signal Priority (PT09), ITS Data Warehouse (DM01), and Performance Monitoring (DM02), implement additional signal priority and data archive data flows to the Sub-regional Architecture. The TSP service package PT09 has been integrated into the NYCSRA 2022 update with the existing Transit Vehicle Tracking (PT01) and Traffic Signal Control (TM03) service packages.

The 2018 update of the TSP PSEAR initially introduces two new service packages, ITS Data Warehouse DM01 and Performance Monitoring DM02 for inclusion in the NYCSRA. The following Figure 2: PT01 - Transit Vehicle Tracking, Figure 3: PT09 - Transit Signal Priority, Figure 4: TM03 - Traffic Signal Control, Figure 5: DM01 - ITS Data Warehouse, and Figure 6: DM02 - Performance Monitoring, contain the New York City Sub-regional ITS Architecture drawings depicting these service packages and data flows.

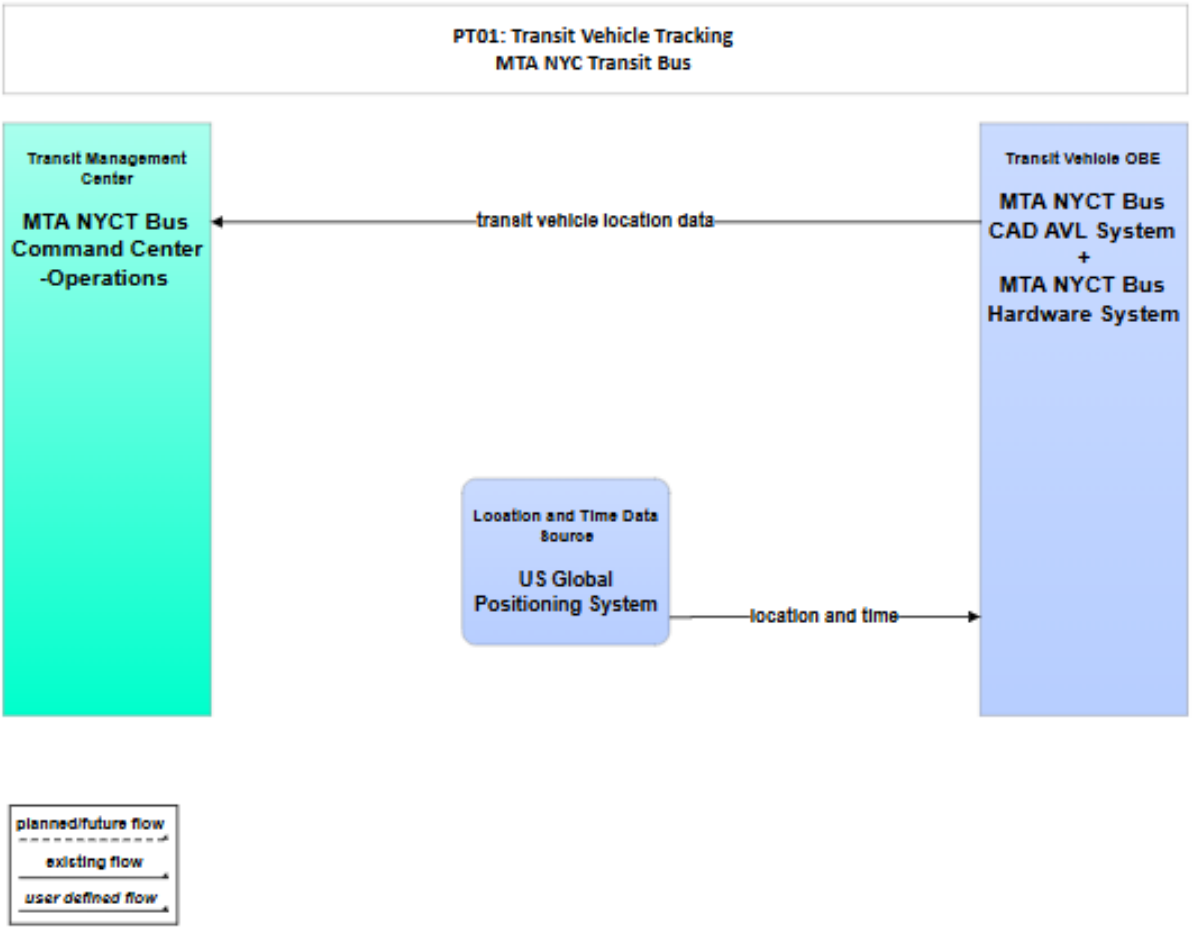


Figure 2: PT01 - Transit Vehicle Tracking

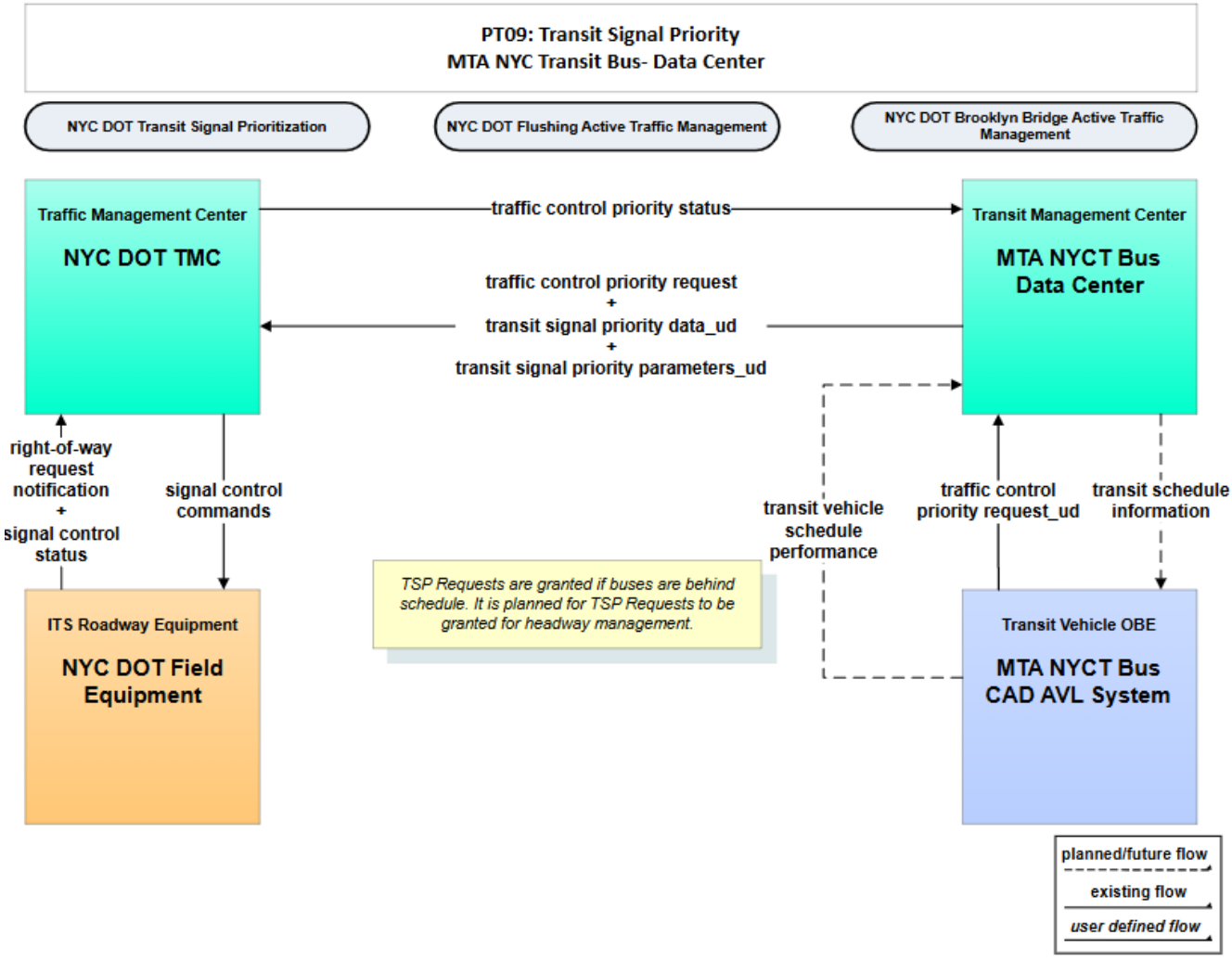


Figure 3: PT09 - Transit Signal Priority

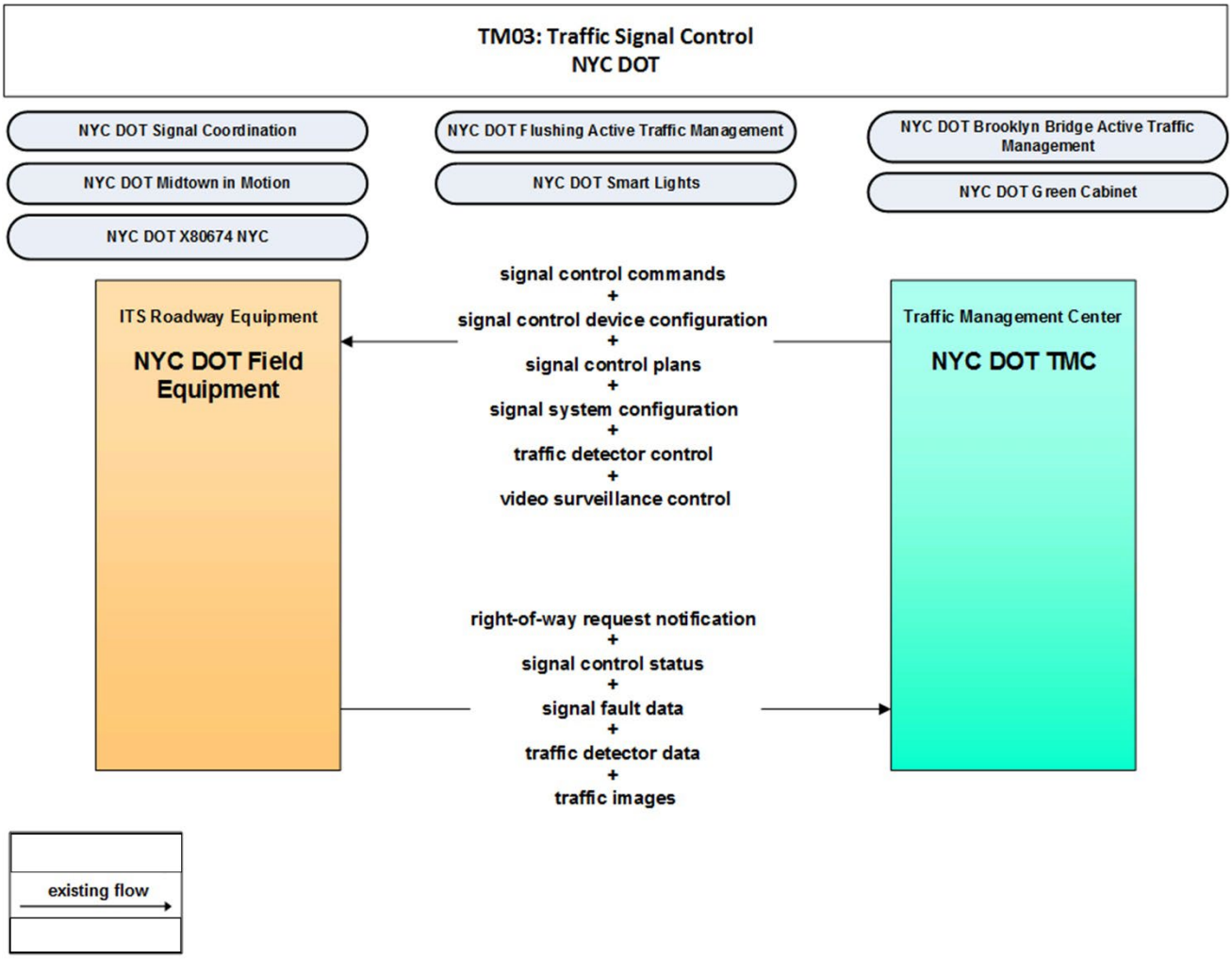


Figure 4: TM03 - Traffic Signal Control

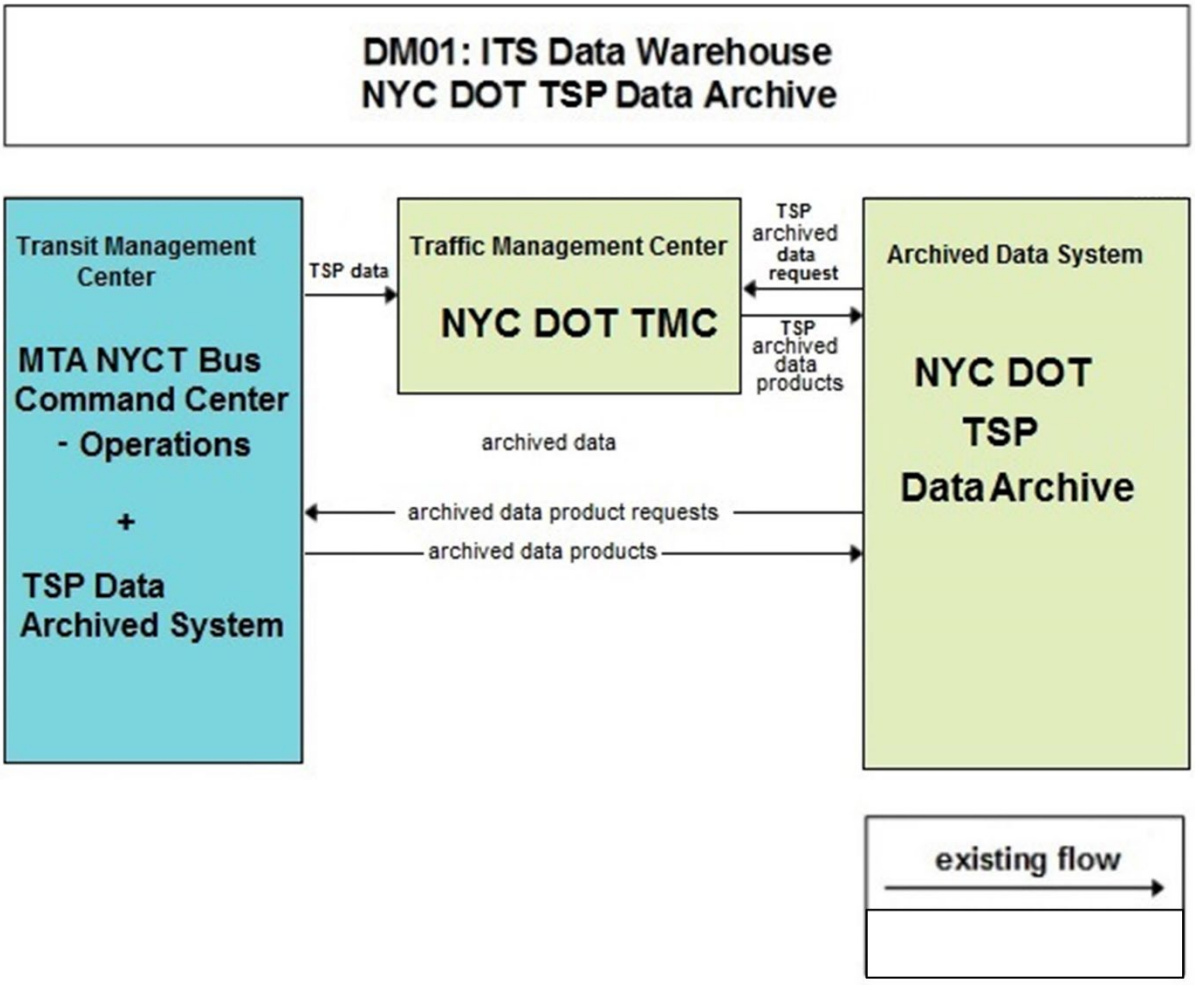


Figure 5: DM01 - ITS Data Warehouse

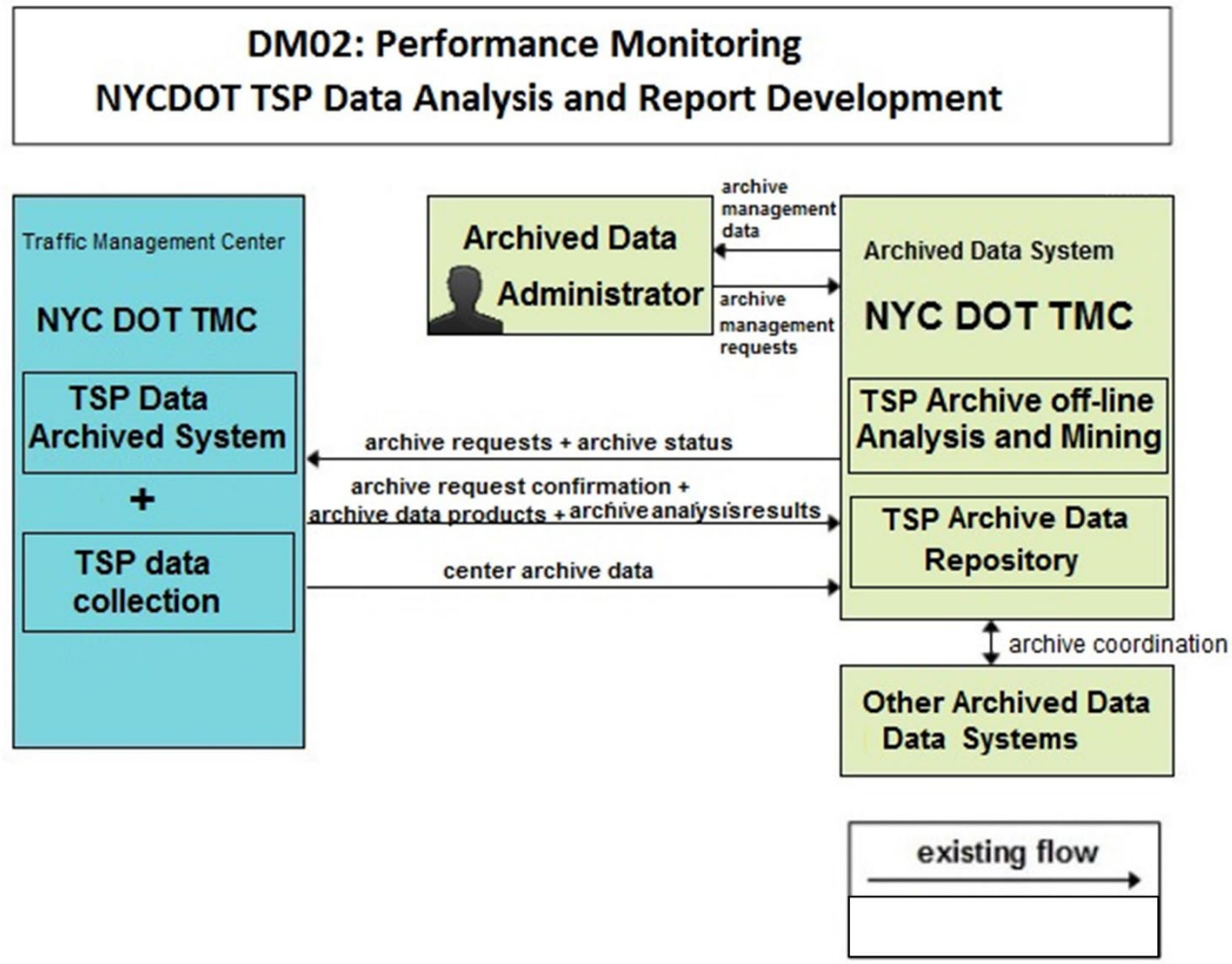


Figure 6: DM02 - Performance Monitoring

The project adds the following architecture flows as shown in the service package diagrams in Figure 2, 3, 4, 5 and 6. These flows are:

- Traffic control priority request
- Archive Data Requests
- Archive Data Products

The project modified the following architecture flows:

- Position fix
- Transit vehicle location data
- Transit vehicle schedule performance

= The Transit Signal Priority (TSP) project leverages the direct data integration between the NYC DOT Traffic Management Center (TMC) and the MTA NYCT Bus Data Center, as outlined in the updated architectural workflows. This approach is considered optimal for citywide deployment because it minimizes the need for additional field hardware while enabling centralized storage and management of TSP data within the NYCDOT TSP Data Archive Warehouse.

Additionally, the MTA NYCT Bus CAD/AVL systems, which are already installed on buses, continuously provide real-time vehicle location data. This information is incorporated into TSP

requests and transmitted from the NYCT Bus Command Center to the TMC warehouse, supporting efficient system operations and data-driven decision-making. This is a complex project that demonstrates the viability of an alternate TSP approach/architecture and develops the infrastructure to support TSP operations on a city-wide basis.

Since 2018, NYCDOT has been successful in migrating from their city-wide wireless network (NYCWiN) to the Traffic Safety Network (TSN), which has significantly improved the support and reliability of TSP operations on a city-wide basis. TSN access for both stationery (for example traffic signal controllers, video cameras, and emergency call boxes) and moving vehicle applications, along with TSP services in the field.

This project focuses primarily on enhancements to the central TSP system, including upgrades to core servers and software platforms, and related improvements to transit vehicles and traffic signal controllers. NYCDOT continues to oversee the advancement of its traffic signal infrastructure by addressing signal controllers to support multi-directional TSO requests at intersections. This includes the use of NEMA (National Electrical Manufacturers Association) based configuration for adaptive signal operations and dedicated bus turn phase, all aimed to improving NYCT bus performance. Signal control device configurations and timing plans are also being refined throughout the TSP implementation process to align with NYCDOT's operational goals. Looking ahead, NYCDOT and NYCT are working toward a more intelligent TSP system capable of leveraging real-time traffic conditions, bus schedule performance, signal status, and MTA vehicle location data to improve bus arrival time predictions. Originally introduced in 2010, the TSP program has since expanded to reduce bus travel times, improve intersection safety, promote transit use, and enhance system accessibility. Today, TSP continues to strengthen conventional bus operations by prioritizing bus movements at signalized intersections, leveraging advanced technology to improve traffic flow and overall system efficiency throughout the five boroughs.

As of April 2026, NYCDOT had deployed approximate 160 transit vehicles with over 5300 total studied signalized intersections for TSP, and over 4,000 intersections enabled with TSP. Figure below shows all enabled intersections along the five boroughs.



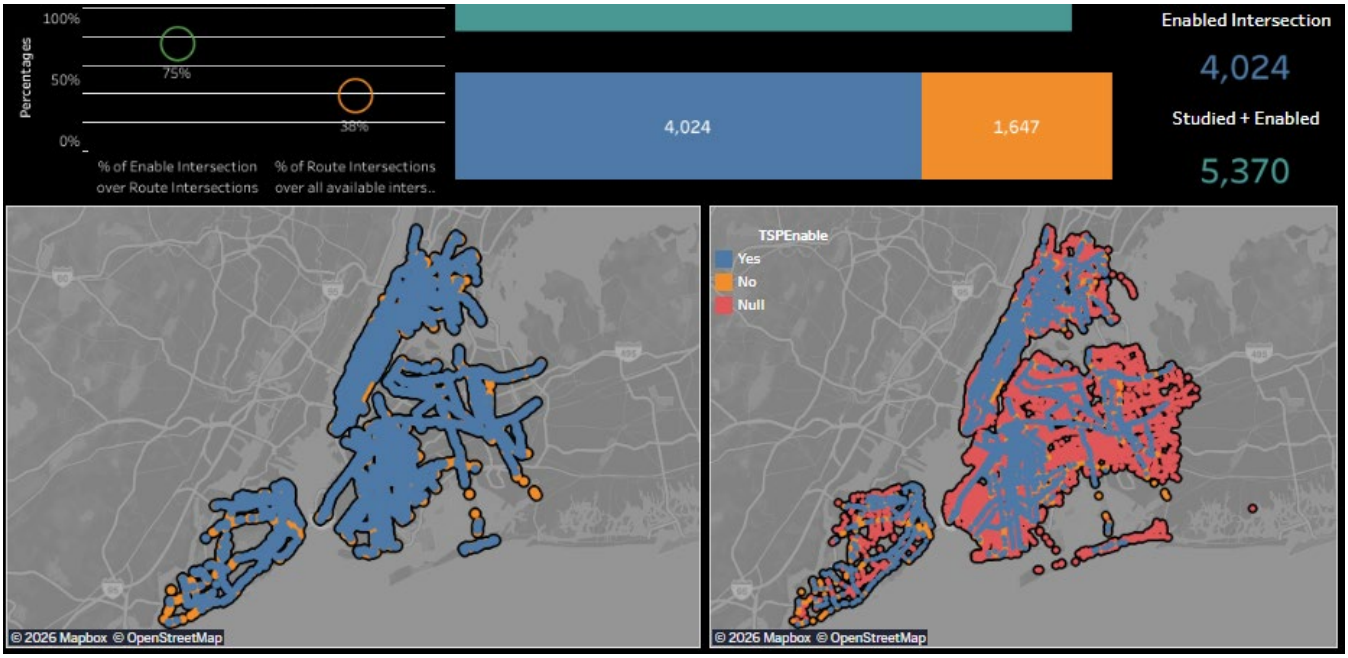


Figure 7: TSP Project City-Wide Area Location

On a separate project, the NYCDOT deployed an ITS Data Warehouse (service package DM01 in ARC- IT Version 9.3) that archives data from the ITS systems at the NYCDOT Traffic Management Center.
The archived data includes TSP message logs and traffic signal controller logs.

Using archived and static Transit Signal Priority (TSP) data, NYCDOT produces post-processing performance reports to monitor and evaluate TSP operations along bus corridors where the technology is deployed, consistent with ARC-IT service package DM02 (Version 9.3).The program processes and archives approximately 5.6 to 6 million records daily, supporting advanced analytics, ongoing research, and the development of new operational models. and provides reports.

The reporting framework integrates multiple data sources, including bus TSP message logs, traffic signal controller logs, and TSP parameter data. These inputs feeds into TMC dashboard portals, which generate daily summary emails highlight key performance metrics, system conditions and anomalies for troubleshooting. For example, operators monitor TSP call performance through layered dashboard views to identify when and where communication drops occur. Once a time window is isolated, detailed message transmission analysis can reveal issues such as synchronization delays that cause messages to fall outside acceptable time thresholds, enabling targeted reporting and corrective action.

These reports evaluate the operational status of TSP-enabled intersections, track daily accepted TSP requests and verify data flows across TSP data centers (PT09). They also support corridor-level analysis by calculating travel times for individual bus trips, including segment travel times between successive TSP-equipped intersections.

In addition, Tableau- based dashboards reports key mobility and reliability metrics such as average travel times by route and direction, the volume of TSP requests at individual intersections, and the distribution of TSP outcomes—including no action, red truncation, and green extension. Many of these metrics are presented graphically to support interpretation. Collectively, these performance monitoring tools enable effective troubleshooting, validation, and fine-tuning of TSP corridors, particularly during initial deployment phases.

2.2 Participating Agencies Roles and Responsibilities and Concept of Operations

As can be seen in the NYCSRA figures above, the project's primary stakeholders are the NYCDOT and the New York MTA. These two primary stakeholders comprise many sub-organizations, each having a significant contribution to the project. In addition to these primary stakeholders, several additional organizations have oversight and financial ties to the project and are referred to as external stakeholders because they do not have daily operational responsibilities.

Several external private sector organizations are also stakeholders in this project. These companies provide their expertise, goods, and services to the primary stakeholders. This relationship indirectly makes them significant stakeholders in the successful implementation of the project.

The following sections discuss these organizations and their role on the project team and details as to the organizational relationships between the team members and the responsibilities of the organization.

2.2.1 System Owners

The New York City MTA and the DOT are the project's relevant stakeholders. All facilities and infrastructure deployed fall under their control. Each organization is responsible for a portion of the overall architecture. Their goals and interests are shared in achieving the project's benefits. The key to the TSP project expansion is the deployment of TSP capable transit vehicles and their integration into the TSP system.

MTA is responsible for on-board bus TSP components and communication between the bus and the central system components. The MTA operates buses through two organizations, New York City Transit (NYCT), and MTA Bus. The NYCT software-based TSP system utilizes MTA Bus Time™ equipment capabilities to establish communication between the transit vehicles and MTA transit management center. All MTA buses have the MTA Bus Time equipment installed and have the capability to participate in the TSP program throughout the City.

NYCDOT controls and is responsible for the traffic management center (TMC) and controls the traffic signal behavior. The NYCDOT includes Systems Engineering, Traffic Signals, and the Traffic Control System operations units.

Communications from TMC to the field traffic signal controllers are provided by the Traffic Safety Network (TSN) using commercial wireless-network services. NYCDOT are responsible for operational issues and use of this network, along with their partners.

The City of New York Council enacted Local Law Int 1557-2019, Version A (Five-year plans for city streets, sidewalks, and pedestrian spaces) on October 22, 2019. The law requires NYC to "implement transit signal priority in at least 750 intersections along bus routes during the first year {2022} of such {a master} plan and at least 1,000 intersections during each subsequent year of such plan or until transit signal priority is implemented in every intersection where such installation is feasible along every bus route where buses capable of utilizing transit signal priority are operated." As of 2026, NYCDOT's TSP program includes evaluations at over 5,300 signalized intersections, with more than 4,000 intersections activated for TSP, and ongoing efforts to study an additional 750 intersections during 2026.

NYCDOT and MTA utilize the services and technology of numerous external organizations. These contributors and their roles in providing the transit signal priority service are listed in Appendix C.

2.2.2 Concept of Operations

A Concept of Operations document titled "Transit Signal Priority (TSP) Concept of Operations" has been prepared by the MTA and is referenced in the bibliography. The following operational description is based on Section 4.3 High-level Conceptual Description of the System from the report. The reader is referred to the original report for more detailed insight into the concept's background.

The cycle of operation of TSP from a transit perspective is based on a single revenue trip for a particular transit vehicle. At the start of a revenue trip, a centralized dedicated server will send the bus the needed data for all TSP-enabled traffic signal controllers along that trip. At the appropriate approaches to those signals, the transit vehicle's onboard computer system will send TSP request messages to the centralized server. This server resides within the MTA NYCT Bus Command Center shown on Figure 2: PT01 - Transit Vehicle Tracking.

The server in turn relays appropriate request messages to NYCDOT's TMC, which manages the traffic network. The TMC evaluates the requests and extends or hastens the green time at the intersection traffic control signal. From transit perspective, the TMC is an external system that provides services without directly interacting with the transit vehicle. Neither the customers nor the bus operators interact with the TSP system.

System behavior is driven by configurable parameters, wherever possible, but the amount of interaction with traffic control system operators/users, transit vehicle drivers, and transit staff will be minimal. The major tasks are limited to checking or updating the software or operating parameters.

2.2.2.1 Revenue Trip Start

Equipped buses will be continuously aware of their positions via the enhanced GPS already installed by the MTA Bus Time Server (also referred to in this document as the "Bus CIS Server" or BCS). The GPS' enhancement is "dead reckoning", which will allow the unit to estimate the bus's position, even if the GPS signal is lost – a common occurrence in New York City's "urban canyons".

The onboard system first identifies the start of a given revenue trip. This event could be triggered through a change to the Destination Sign Code (DSC) on the bus to one associated with a specific revenue trip.

The bus will identify this potential trip to start to the TSP server.

The central server will verify whether this event represents the start of a revenue trip, by checking the value of the sign code. It may also (or instead) check the bus location and schedule data via its interface with the BCS. If the event is not a revenue trip start, nothing more needs to be done.

If it is the start of a revenue trip, the central server will obtain geospatial trip path information for the route path from the BCS. The central server will enrich this data using its own database to prepare and download a full description of all the TSP-enabled traffic signals along that trip path to the bus.

This process is repeated at the start of each revenue trip, allowing any equipped bus to implement

TSP on any route. In this manner, the system will provide access to TSP services throughout the City's signal system.

2.2.2.2 Bus Behavior at a TSP-Controlled Traffic Signal

For each approach along a route to each signal in the system, there will be a defined (and configurable) area on that approach called the "check-in zone". Each approach also has a corresponding point of exit, called the "check-out zone". This is illustrated in Figure 8 below.

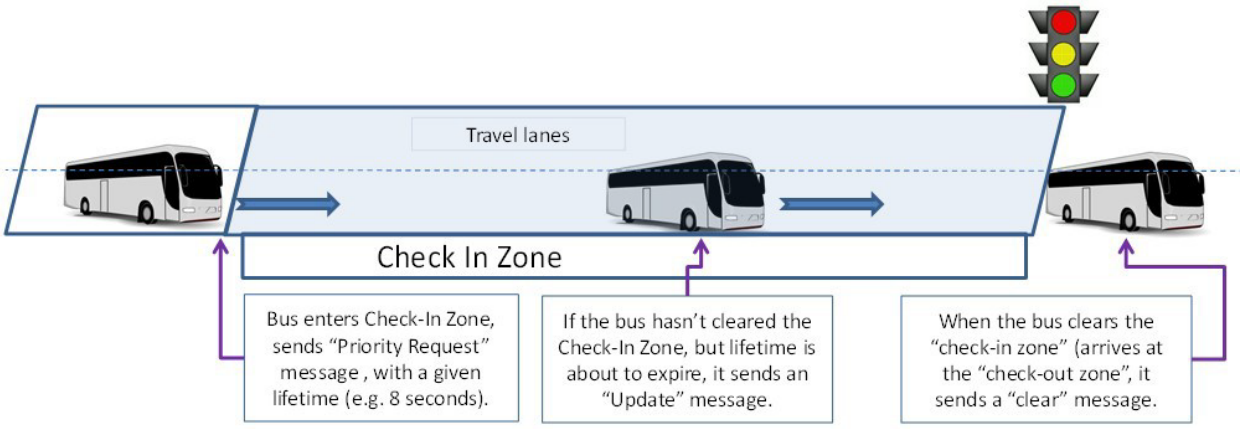


Figure 8: Bus Behavior at A TSP Equipped Signal

The transit vehicle's onboard computer system recognizes when a bus enters the check-in zone and transmits a "priority request" message to the central server. These messages identify the bus, the associated signal, and a lifetime for the request.

When a bus is still in the check-in zone prior to the expiration of the request lifetime, typically due to traffic conditions, it sends an "update request" to the server, to potentially extend the request.

Once a vehicle hits the check-out zone (that is, it exits the check-in zone), it sends a "clear" message to the central server. The TMC forwards a clear message to the traffic controller which terminates TSP consideration for the bus.

If the bus has not cleared the check-in zone before the end of the request lifetime, the bus may send (possibly multiple) "update" messages to request further extended green time. The TMC forwards them to the traffic controller which then evaluates whether to grant hastened or extended green time and may or may not grant the requests. If not granted, the (repeated) update message(s) will simply have no effect. The transit vehicle's on-board TSP software will set a (configurable) limit to the number of update messages sent by a bus for a given check-in zone.

2.2.2.3 Centralized Server

The centralized component of the system is the TSP server subsystem.

Communications between the bus and the server are two-way. The two sub-systems communicate at the start of the trip to set up the initial data as described above. However, while all requests are acknowledged, priority requests flow one way: bus to NYCT fleet server, NYCT fleet server to TMC. This is illustrated in Figure 9. On the figure, EPL stands for Ethernet Private Line which provides communication between the TMC priority server and the NYCT fleet server. Also, on the figure, ODK stands for Operator Display Keyboard and is the onboard device used to input the destination sign codes by the bus operator.

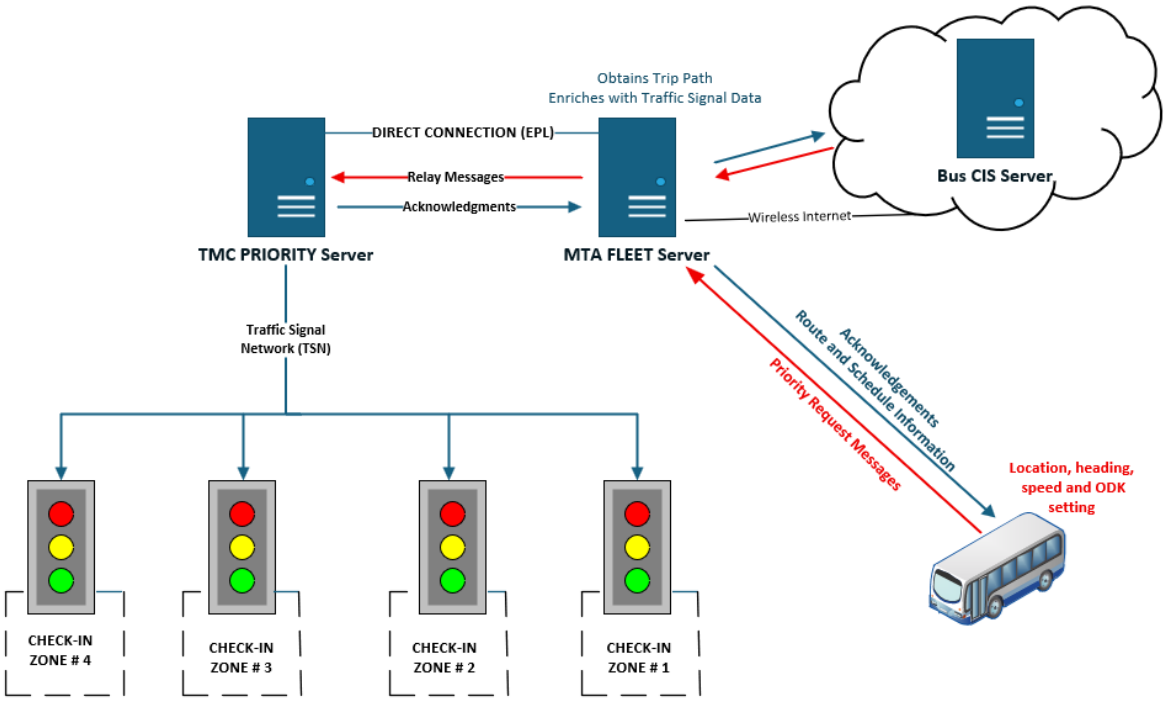


Figure 9: TSP Message Flow

The NYCT fleet server logic will evaluate whether to forward request messages from buses to the NYCDOT TMC. For example, based on configurable operating parameters, it may withhold requests for buses that are ahead of their schedule. The server will acknowledge receipt of all messages from the buses, however.

The TMC will acknowledge receipt of all requests (TMC priority server) and evaluate how to act upon them according to its own logic. The TSP requests are forwarded to the Traffic Control System (TCS), and if the borough, bus route and intersection are configured for TSP operation, the TMC priority server forwards the requests to the intersection traffic controllers along the bus route. The transaction of the bus initiating a TSP request to the receipt of the request by the intersection traffic controller typically occurs in less than a second.

NYCDOT has been advancing upgrades to its TCS (Traffic Control System) to support NEMA operations, laying the groundwork for future implementation of adaptive signal control. These enhancements are aimed at improving the accuracy of transit vehicle estimated arrival times while optimizing overall roadway performance.

Under the current system, signal controller firmware may occasionally allow TSP intervals to carry over into subsequent cycles, potentially causing delays for buses and general traffic. To address this limitation, NYCDOT is testing updated firmware designed to better manage cycle transitions, reduce unnecessary multi-cycle extensions, and enhance overall operational efficiency. The optimized controller firmware incorporates improved logic and algorithms to evaluate whether a given estimated time of arrival warrants a green extension or a red truncation. This determination is based on when the request is received within the signal cycle, helping to avoid unnecessary adjustments to phase durations when no operational benefit is achieved.

These improvements also enhance configuration flexibility, including adjustments to reservice time settings, which help sustain continuous TSP operations and enable controllers to handle multiple priority requests across different traffic directions. NYCDOT is actively evaluating these

upgrades by monitoring system response and behavior under various priority rules and timing configurations to ensure reliable and efficient intersection performance.

2.2.2.4 Responsibilities

This section discusses the responsibilities agreed to by the two system owners, MTA and NYCDOT. The allocation of these responsibilities creates two "sub-projects" that results in a single interface point between each agency's technology contributions. The approach provides flexibility for each owning organization to contract and manage its technology contributors as well as minimizes points where technology decisions could disrupt the end-to-end data flow required.

2.2.2.5 MTA Responsibilities

MTA and its divisions, New York City Transit Department of Buses and MTA Bus, have several divisions which will share the administration and maintenance of the transit components of the TSP system. The MTA Information Technology group (MTAIT) maintains information systems within the agency. This includes providing and maintaining servers, core network infrastructure, and data centers. The Department of Buses (DoB) has a technology and engineering group, Bus Technology Systems, that supports DoB operations. They serve in engineering and developing onboard technologies in addition to long-term server and on-board software maintenance.

Installation of the TSP application to the buses happen over the air (wireless) and maintain autonomous throughout the five boroughs. The hardware of the TSP application is in fact multipurpose, including equipment shared with other existing systems such as the Bus Customer Information System (interfaces with its wireless communications modem) and CAD/AVL system (interfaces with its GPS and installed on computers) thus reducing the footprint on the bus and physical demands .

Previously in earlier deployments, an onboard TSP computer terminal was installed. In further developments, a terminal is no longer required and instead, software is installed onto a pre-existing CAD/AVL system.

This application will generate the TSP requests based on information from the GPS device hosted on the CAD/AVL system. Several organizations are available to support these activities. The Department of Buses and its maintenance departments, which, among other functions, maintains onboard equipment in the field, including device and data networks. The maintenance responsible for on-board Bus Customer Information System (Bus CIS) equipment is currently handled by a 3rd party contract. The maintenance vendor is responsible for maintaining inventory and liaison with the Department of Buses for accessing buses.

Responsibility for communications between the buses and the other system components will reside with the MTA.

The MTA coordinates the rollouts of bus routes with NYCDOT. The two agencies jointly plan any expansions or extensions to the systems (in as much as they affect transit vehicles) and share project data that will assist with future decisions.

Maintaining the application and distribution of software to buses will be the responsibility of MTA Bus Technology Systems.

2.2.2.6 NYCDOT Responsibilities

NYCDOT is responsible for the signal timing of traffic signal controllers. This responsibility includes parameters that control the TSP operations as well as defining the intersection locations where TSP will or will not be available.

Communication between the TSP system and the traffic signal controllers is the responsibility of NYCDOT. This responsibility will consist of monitoring and identifying communications failures. Responsibility for the maintenance of the communications infrastructure hardware is divided into two parts: NYCDOT will be the first responder to apparent problems with the field equipment including replacement of wireless routers, while the selected commercial wireless communications vendor(s) for the TSN will assume responsibility for the communications from TCS to the traffic signal controllers.

NYCDOT will be responsible for ensuring that the TSP service does not cause undue disruption to traffic operations. NYCDOT will also make sure that the coordination of the signals is always maintained. As such, it will be responsible for modeling the traffic operations to identify potential issues prior to field operations. NYCDOT has developed reports that post-process TSP data archived in its ITS warehouse to monitor intersection traffic signal controller TSP actions, including number of red truncations, green extensions and no actions. Individual bus travel times are also calculated along TSP corridors.

NYCDOT maintenance of its facilities is not expected to change due to this program. The current traffic signal controllers already support the TSP messages using the National Transportation Communications for Intelligent Transportation System Protocols (NTCIP) and a few additional TSP specific objects. The existing hardware does not need to be augmented or modified to meet the project's goals. However, future TSP deployments may incorporate enhancements through emerging technologies, such as video analytics systems. These tools could complement the existing infrastructure by supporting adaptive signal operations, improving the accuracy of bus estimated arrival times, and enabling real-time traffic monitoring. With the introduction of these potential enhancements, the responsibility of the client would expand to include the evaluation, deployment planning, and ongoing management of such technologies. This may involve coordinating installation, ensuring system integration with existing TSP architecture, maintaining the additional equipment, and overseeing data quality and operational performance to support continuous system optimization.

System communications is critical to the success of the TSP system. The transit vehicles pose an interesting issue as they are moving TSP request sources. This mobile source issue can be addressed with an appropriate communications infrastructure. Likewise, there is a wireless network connecting the TMC with the traffic signal controllers and it too is subject to external disruptions.

NYCDOT will be responsible for monitoring the end-to-end communications to maintain the system. It will need to verify the operation of each link at a high level and verify that each transit vehicle's priority requests are received at the appropriate intersection. The NYCDOT has developed a TSP communications transmission dashboards that it uses to post-process TSP communication data archived in its ITS warehouse at its TMC and uses the dashboards to identify possible communications problems.

2.3 Needs and Associated Functional Requirements

This section describes the project's needs and the requirements satisfying those needs. The needs reflect the information and actions necessary to provide signal priority and monitor its operation. From these needs a series of requirements are developed to fulfill these needs. The requirements are technology neutral and are written so that each can be tested. A Needs to Requirements Traceability Matrix (NRTM) is provided for on-going verification and management of the requirements throughout the projects life- cycle. (Refer to Section 2.3.3)

2.3.1 Needs

While the basic project need is to provide priority to transit vehicles, a number of specific needs must be satisfied. These needs pertain to the transit vehicles, transit route schedules, traffic signal controllers and their timing parameters. The needs are listed in the following sections.

2.3.1.1 Need for Transit Route's Itinerary

The system needs to know the planned path and time schedule (for example, itinerary) for each route. These descriptions are the information transit riders rely upon for trip planning purposes. This is the base information for determining whether an assigned, in-service, transit vehicle is on-time or behind schedule.

2.3.1.2 Need for Transit Vehicle Identification

Each transit vehicle needs to be uniquely identified. With over 5700 vehicles in the fleet, flexibility is needed to cover the existing and future routes.

2.3.1.3 Need for Transit Vehicle's Transit Route Assignment

Transit vehicles are assigned to various routes depending on the availability of the transit fleet and staffing. Transit vehicle route assignments must be flexible so that the agency can adjust to vehicle breakdowns and other events beyond its control.

2.3.1.4 Need for Transit Vehicle's Revenue Status

Transit vehicles must be making a revenue trip (for example, in-service) to make priority requests. Out- of-service vehicles will not receive priority. The service status may be linked to the Destination Sign Code (DSC) displayed on the exterior of the vehicle and driver inputs prior to beginning the trip.

2.3.1.5 Need for Transit Vehicle's Location

Three pieces of information are needed regarding the transit vehicle to enable the TSP operation. The transit vehicle's location identifies the next traffic signal controller to which the priority request can be sent. It also defines when the vehicle has passed the intersection and priority service is no longer needed at that intersection. The location needs to be highly accurate as typical speeds and intersection spacing mean transit vehicles can pass through adjacent intersections within 7 seconds (using 25 MPH vehicle speed and 257 feet intersection spacing).

The transit vehicle's speed and heading are also needed to supplement occasions when GPS locations are unavailable or suspect due to signal losses. The speed is also needed to determine whether the transit vehicle may clear the target intersection or be stopped by its signal.

2.3.1.6 Need to Know Transit Vehicles Approaching and Clearing An Intersection

Transit vehicles should only request service from intersections they are currently approaching. They should also indicate when they are through an intersection to limit signal timing changes. This need constrains the TSP operation to individual vehicle-intersection "pairs" and constrains the architecture so that the locations of all vehicles do not need to be tracked in real-time.

It also establishes the need for zones (for example, area) to identify vehicles approaching an intersection check-in zone and clearing check-out zone and intersection. These zones are also referred to as trigger zones. Trigger zones normally occur sequentially (for example, intersection A check-in, intersection A check-out, intersection B check-in, intersection B check-out, etc.) however they may overlap where intersection spacing is short (for example, intersection A check-in, intersection B check-in, intersection A check-out, intersection B check-out).

The zone locations will need to vary by time-of-day as traffic speeds vary and signal timing plans vary by time of day. Average intersection approach speeds will differ for the morning and evening peaks as well as the mid-day period, thereby impacting the calculations of travel time from the check-in points to the intersection.

2.3.1.7 Need for Transit Vehicle Priority Request

The transit vehicle needs to request priority service at the intersection it is approaching. Requests to other intersections are counterproductive as intersection signal timing, traffic queues, and emergency vehicle operations may significantly alter the transit vehicle's trajectory to said intersections. The point at which the vehicle will make its priority request may be upstream of several intervening intersections due to block spacing and vehicle speeds.

2.3.1.8 Need for Updating Transit Vehicle's Priority Request

A transit vehicle needs to be able to update its priority request as it may encounter stops and delays in travelling past the intersection it is approaching.

2.3.1.9 Need for Calculating the Transit Vehicle's Variance from Planned Schedule

The transit vehicle may not require priority when it is ahead of its itinerary. Therefore, the difference between the transit vehicle's current schedule and its planned schedule is a critical input to requesting/granting priority.

2.3.1.10 Need to Determine Whether to Grant Priority Request

This is the focal need for the system. This decision may be based on the schedule variance and encompasses any other limiting factors.

One limiting factor is whether the transit vehicle is sufficiently close to an intersection to make a request. A "proximity zone" around an intersection is needed to verify that requests are being made by vehicles in the immediate vicinity of the intersection. This zone provides a protective mechanism that makes it possible to reject requests from vehicles that are located outside of the intersection's actual signal priority area. This mechanism prevents transit vehicles from making requests to intersections that the transit vehicle cannot possibly reach from the vehicle's current location.

2.3.1.11 Need to Communicate Granted Priority Request

The decision to grant priority needs to be communicated to the traffic signal controller which implements the signal displays. Granted requests do not need to be communicated to the transit vehicle as the operator is governed by the traffic conditions and traffic signal display. The system does not need to communicate denied requests to the traffic signal controller or the transit vehicle.

2.3.1.12 Need for Traffic Signal Controller to Implement Priority Request

The traffic signal controller needs to implement the priority request utilizing the pre-programmed priority timings within its database. These parameters need to be configurable by the traffic control system.

2.3.1.13 Need for Transit Vehicle Priority Clearance

The transit vehicle needs to indicate that it has cleared the intersection so that priority signal timings can be terminated, and normal signal timings can be restored.

2.3.1.14 Need for Control Priority to Avoid Adversely Impacting Traffic Conditions

The traffic signal system needs to maintain coordination of the traffic signals because too many disruptions to the traffic signal timing may induce additional traffic congestion. The system needs mechanisms to limit the use of priority when operators determine that priority is adversely impacting
traffic operation. Whereas the priority is controlled at individual intersections, this need is for control of the process at higher levels such as arterials, routes, jurisdictions, and system.

2.3.1.15 Need for Priority Activities to Appear on Existing Traffic Control System

The TSP actions will perturb the actions of the existing traffic control system timing. Therefore, there is a need for the traffic control system to observe these actions and be able to display and report that they are occurring.

2.3.1.16 Need for Reliable Communications

This system is distributed such that TSP requests will be made by moving vehicles. For the intersection to "know" that the transit vehicle is approaching, reliable communications are essential. The communications environment is "noisy" and subject to short duration disruptions. Messages will need to be acknowledged to confirm their receipt. Messages may be subject to latencies due to the characteristics of the selected communications media and therefore, the system needs to be able to handle normal communications latencies.

2.3.1.17 Need to Evaluate Priority Operations

To track and analyze the system's operation, a log of the priority transactions should be kept and maintained. These logs are needed to audit transactions and verify the system's decisions. System components are embedded in moving vehicles and operations occur in short time epochs; therefore, it is convenient to capture real-time data for later processing.

2.3.1.18 Need to Modify Priority Parameters

The system's parameters need to be modifiable so that the system can be tuned to changing conditions; such changes need to be regulated such that changes are made by authorized personnel.

2.3.2 Adaptive TSP Additional Needs and Functional Requirements

2.3.2.1 Need for Real-Time Transit Vehicle's Location

Accurate location data is critical for reliably predicting bus arrival times, since typical operating speeds and intersection spacing allow traffic signals to make precise, real-time timing adjustments. Without current location information, signal priority may be activated too early, too late, or unnecessarily, reducing benefits for transit vehicles and causing disruptions to other traffic.

2.3.2.2 Need for Geofence Approach to Calculate Estimate Time of Arrival

The system must define an algorithmic detection zone upstream of an intersection that uses both historical and real-time data to predict bus arrival time and assess the effectiveness of a TSP request. Establishing this zone where bus movement becomes more predictable enables more accurate ETA calculations and more reliable, actionable signal timing adjustments.

2.3.3 Functional Requirements

Due to the selected architecture and the embedded nature of the system, the requirements are written with a predisposition to their assigned hardware components. This approach is taken with the procurement process in mind so that procurements can be performed independently. The information partitioning within the architecture acknowledges that the transit vehicle and/or the

MTA systems are where route- schedule information is available (schedules are unknown to the TMC systems) and therefore the transit vehicles and/or fleet management server need to assess and address schedule adherence.

The requirements list resides in the Requirements Table to accommodate the tracing and status information provided with the requirements. The tracing information identifies the source of the requirement. The status information identifies the project phase for implementation as some requirements will be incorporated during future project phases. Project phase 1 indicates that the requirement was addressed by the initial implementation.

All requirements listed in the table are considered to be mandatory except for those listed with Phase 2 (2) or future (F) in the phase (Phs) column. These requirements will be addressed through additional projects.

2.3.4 Needs to Requirements Traceability Matrix (NRTM)

The NRTM provides a mechanism for tracking how user needs are addressed by system requirements. It provides information for assessing the system by stakeholders, users, implementers, and evaluators. The NRTM resides in Appendix B.

2.3.5 Constraints

The transit vehicle receives location updates on a once per second basis[1]. With vehicles moving 36.7 feet each second (at 25 miles per hour), location processing algorithms may need to anticipate locations to provide timely input.

The nature of New York's urban canyons leads to frequent loss of signals with GPS satellites. These losses must be considered and accommodated for by additional location referencing techniques to maintain sufficient, reliable location information.

Communications through the traffic control system to the intersection's traffic signal controller can take up to two seconds due to the messaging architecture and the wireless infrastructure, although most of these communications take less than a quarter of a second. These latencies need to be recognized and accommodated by the communications protocols, timing, and operations.

2.3.6 Functional Requirements and "V" Model Cross Linkage Summaries

2.3.6.1 Functional Requirements Summary

The functional requirements for the Transit Signal Priority system to be implemented under the TSP project, are derived from the user needs specified in Section 2.3.1 above, and listed in Appendix A:. These requirements have been assembled, reviewed, and agreed to by the stakeholders NYCDOT and MTA through a series of development meetings.

The addition of these requirements will enhance the sub-regional ITS architecture throughout the City. As the number of transit vehicles with updated onboard TSP expands, the City has been able to enhance transit operations into other corridors after the appropriate data collection, analysis, and traffic signal controller timing plan updates.

2.3.6.2 "V" Model Cross Linkage Summaries

The evaluation of the functional requirements' impact is facilitated by the systems engineering "V" model process developed by the Federal Highway Administration (FHWA). The "V" model, shown in Figure 10, provides the key to understanding the relationships between the front-end activities and its impacts on operations and maintenance on the end users.

[1]MTA/NYCDOT, Transit Signal Priority (TSP) Concept of Operations, Version 0.3, 5/15/2012, Page 40, Section 9.2.6.1

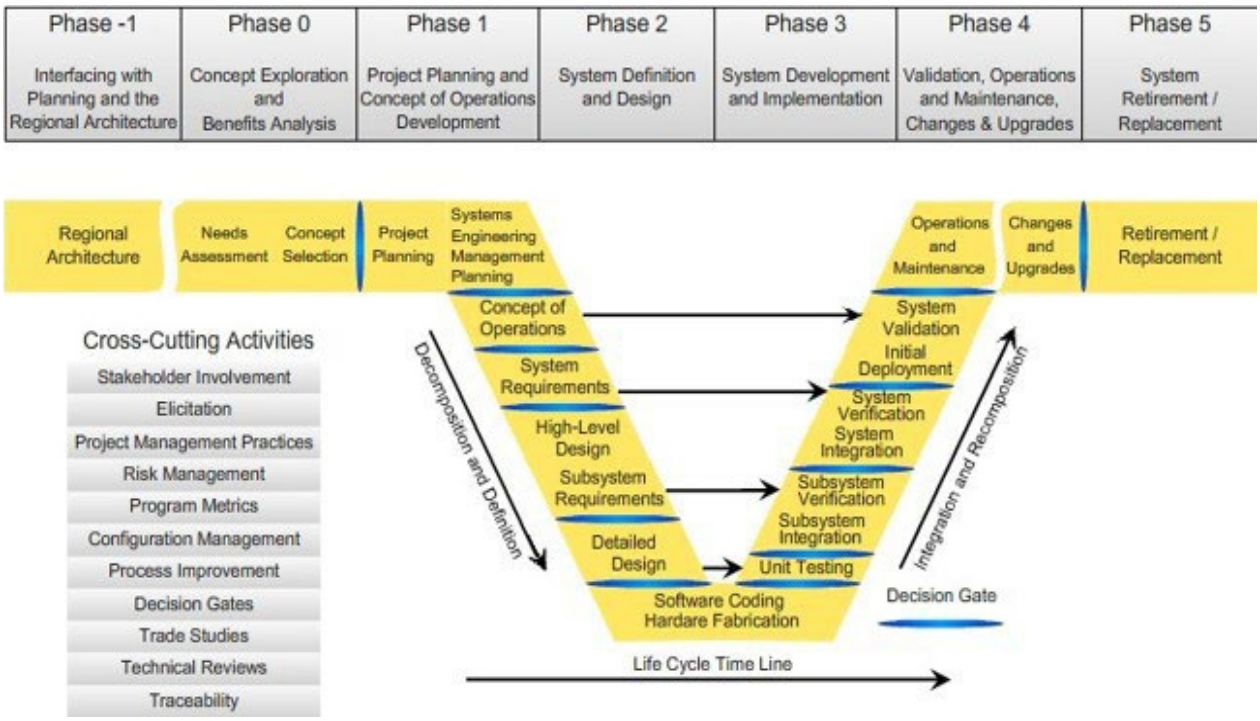


Figure 10: "V" Model Diagram

2.3.6.2.1 Project Scope

The initial TSP project scope was limited to the M15 route in Manhattan from State Street at Peter Minuit Plaza north to East Houston Street at Allen Street/1st Avenue (34 intersections). It included the installation of updated onboard computer terminals on approximately 50 M15 Select Bus Service (SBS) transit vehicles. This scope was completed on March 2014. A before and after study completed August 2014, showed an average improvement of 13.7% in travel time along the pilot M15 route.

The TSP infrastructure put in place covered the entire city except for the equipping of transit vehicles. The project involved little interaction with the transit vehicle operators or traffic management staff after the database has been configured aside from reviewing the logs for operational issues. The NYCDOT and MTA will continue their normal operations after the deployment of the TSP system. The impacts of the deployment are discussed in Section 2.2.3 Concept of Operations above.

Since 2014, the scope of the TSP program has expanded significantly, with approximately 750 to 1,000 intersections evaluated annually for potential TSP implementation. This effort now spans all five boroughs, with a primary focus on improving bus service reliability by reducing delays at signalized intersections. By strategically adjusting traffic signals to prioritize bus movements, the program helps minimize time spent at red lights and supports more consistent travel times. Ultimately, these enhancements are intended to strengthen rider confidence by delivering more reliable and efficient transit service. TSP has been successfully deployed across more than 160 bus routes throughout all five boroughs. The routes included in this deployment are illustrated below, reflecting the broad coverage and continued expansion of the program.

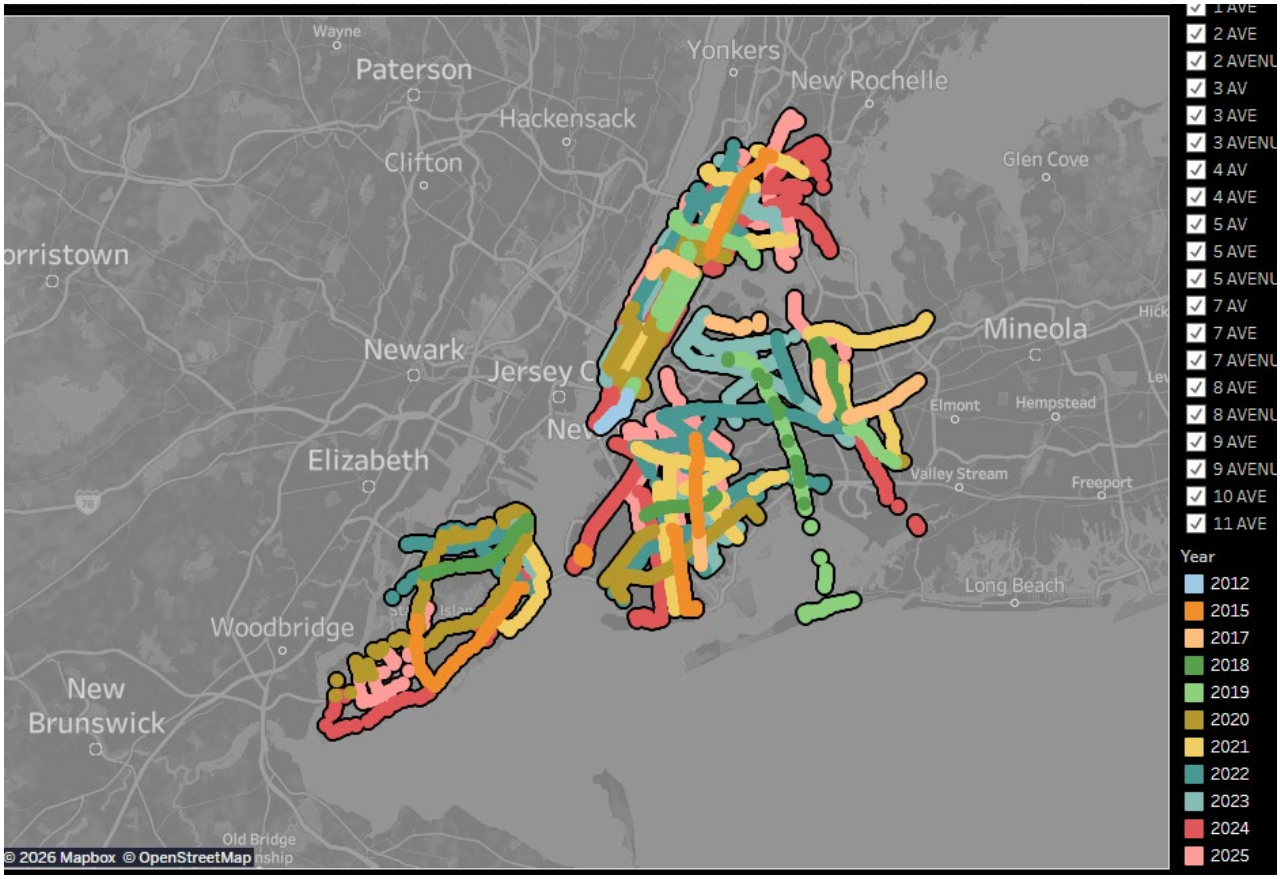


Figure 11: TSP Deployment

Project Goals/Objectives

The project goals and objectives are to improve transit vehicle route travel times.

Project Scope

The project scope is New York City political boundaries.

Project Expectations

The project expectations are to achieve improved transit vehicle operations.

2.3.6.2.2 High Level/Detailed Requirements – System Acceptance

Verification of the system will be performed by inspecting the system logs for data relevant to each requirement. This approach is necessary due to the embedded, real-time nature of the system. The test procedures will identify the requirements to be verified and describe the log data to inspect for verification so that the requirements are fulfilled.

2.3.6.2.3 High Level/Detailed Designs – Subsystem Verification/Integration and Testing

Verification of the individual configuration items will be performed as specified within the procurement documents. The configuration items will be comprised of the various servers to be deployed, their communications interfaces, and the communications media linking them. The verification will demonstrate that each configuration item fulfills its allocated requirements.

2.4 Analysis of Alternative System Configuration and Technology Options

The NYCDOT and NYCT considered several basic architectures for providing the TSP service. This section describes those architectures and their implications over their lifecycle.

2.4.1 Localized TSP- No Longer in Use

2.4.2 Distributed TSP

In a distributed TSP architecture, the TSP requests from individual vehicles are transmitted to a centralized processor for evaluation and disposition. The decisions made by the central process are communicated to the traffic signal controllers for implementation. These decisions could also be communicated back to the transit vehicle and its driver. Figure 12 shows a representative block diagram of this architecture adapted from the NTCIP 1211 Standard's description of Scenario 1.

The centralized architecture provides more flexibility for managing a large network of vehicles and intersections. It provides a single point of update should the decision process or related algorithms need to be adjusted. It also constrains the hardware/software components that must be resident in the transit vehicle. In addition, the distributed TSP approach does not require any additional proprietary hardware at the intersection which minimizes the deployment and maintenance costs.

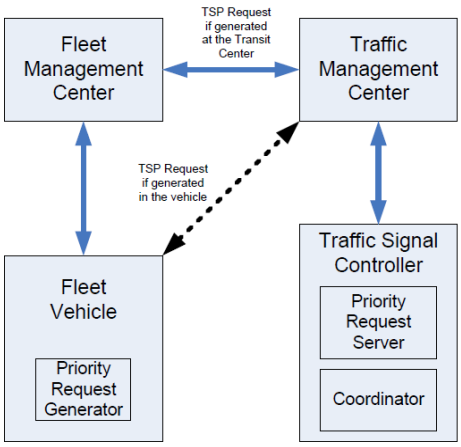


Figure 12: Distributed TSP Sample Architecture

2.4.3 Architecture Evaluation

The local TSP architecture does not meet the MTA's or DOT's current goals and objectives. Its proprietary equipment would be expensive to outfit the existing fleet or would be expensive to move on a limited fleet basis. The local TSP architecture approach also limits the ability of both MTA and DOT to monitor and control the TSP operation. It does not lend itself to incorporating on-time scheduling as an input to the priority request validation. Further, it requires the installation of costly proprietary interface hardware at each intersection with its associated maintenance costs. Central TSP architecture provides the MTA and DOT the ability to control TSP operations and control the equipment necessary to outfit the fleet of transit vehicles. In addition, there is no need for any further equipment at the local intersection; all

intersections can support TSP operation without any field changes – the operators need only configure the TSP operating parameters and download them from the central traffic management system.

The centralized option also allows the MTA and NYCDOT to proceed with their procurement and deployment activities independently. Once an interface between the systems is defined, DOT can proceed to deploy their central system and MTA can proceed with the procurement and deployment of their TSP equipment. **Therefore, the centralized architecture is the preferred alternative and was chosen by the MTA and NYCDOT for deployment.**

2.4.4 TSP and Digital-Twin Model

NYCDOT's future deployment plans include an adaptive TSP approach in which an online model works jointly with MTA and NYCDOT to provide real-time inputs, with an emphasis on accurately predicting bus arrival times during operations. The model will represent selected TSP intersections, simulate short-term traffic conditions, and estimate bus arrival times at the stop bar using both historical and real-time congestion data.

Real-time field data—such as MTA Bus Time, NYCDOT Wi-Fi, video analytics, and other detection systems—will support these simulations. The model will also replicate traffic signal controller logic and responses to TSP requests, producing estimated arrival times and benefit scores to guide adaptive TSP decisions. Model recommendations will be continuously evaluated and refined through a learning algorithm. Enhanced vehicle location data will allow the TSP server to continuously update bus distance and ETA to each intersection, supporting future adaptive functions such as video integration and model-based ETA calculations, with updates transmitted directly to the signal controller.

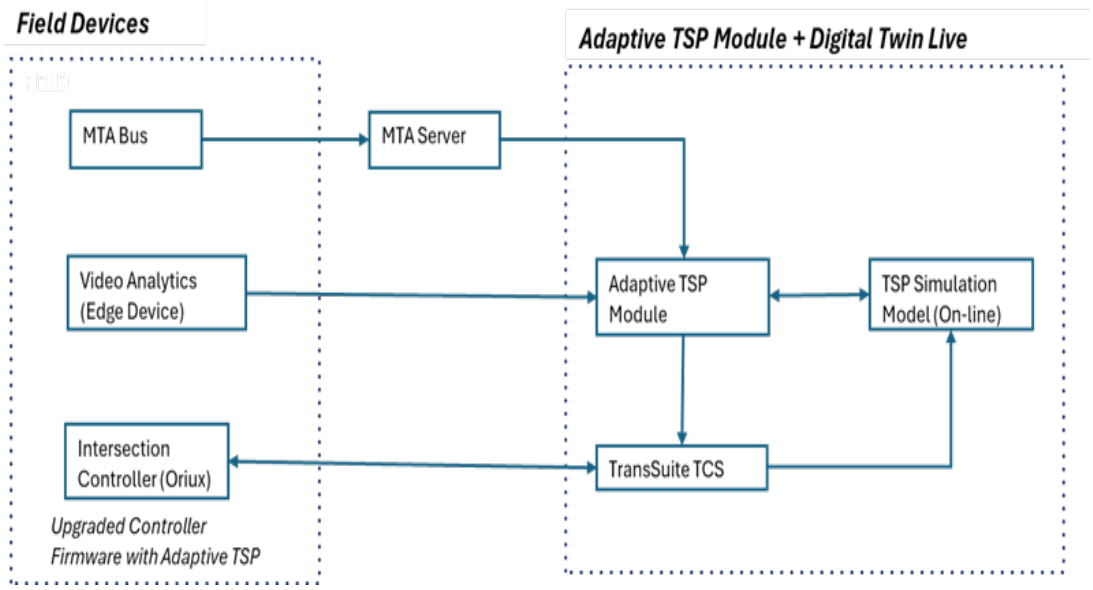


Figure 13: Adaptive TSP Module with Digital Twin

2.5 Procurement Options

2.5.1 Current

The selection of the distributed architecture provides an opportunity for multiple procurement options. The stakeholders may choose to utilize multiple component contracts to obtain experts for the development and deployment of each component. Another approach would be to package all the components together and deal with a single vendor so that responsibility for the end-to-end development of the system resides with one organization. A number of options between these two procurement approaches exist based on the selection of the components into independent procurement packages. The requirements have already been assigned to various components within the architecture and readily support these procurement approaches. A general set of communications requirements are applicable to multiple components and have been identified so that they may be included in addition to each component specific requirement set.

The system components have no significant common hardware requirements. The key concepts linking the components are their time keeping and data communications requirements. This approach provides vendors with flexibility to utilize appropriate hardware that achieves the system goals, and links the systems through the data and time transmissions. Therefore, the interfaces between the components become the key to their successful integration and deployment.

A successful procurement strategy will incorporate testing and integrating the components as well as their interfaces. Each component should be procured and tested independently as well as its interface with the downstream and upstream components. The procurement strategy will also address the end-to-end testing of the system to verify and validate the implementation.

The initial development work for the TSP system, including development of the PSEAR, is funded through a CMAQ grant administered through FHWA (X770.37). This grant is also funding the other work needed to implement TSP along several other corridors city-wide, including needed traffic data collection and analysis, as well as traffic signal controller hardware. Additional corridors have the

potential to be funded through other sources, including FTA grants, local funds, and funds provided by NYCT; the initial test Lower Manhattan corridor was funded by CMAQ, funds flexed to FTA for grant administration. This variety of funds highlights the importance of project management, and ongoing coordination between all involved agencies at the city, state, and federal levels.

Procurement for the TSP program continues to evolve alongside the ongoing development and refinement of the PSEAR framework, ensuring it supports the program's expanding scope and long-term sustainability. The system has benefited from continued investment since its initial deployment, with funding mechanisms supporting both operational improvements and future enhancements.

In addition, NYCDOT has recently been awarded capital funding from the Federal Highway Administration (FHWA) to advance next-generation capabilities through Adaptive TSP. These enhancements incorporate simulation tools, video analytics, and integrated machine learning models to enable dynamic parameter optimization and more robust performance evaluation. The initiative targets selected bus routes with the goal of improving transit reliability and accessibility, particularly for communities with high demand for efficient public transportation.

New York State or other capital funding within the MTA has been secured for the future expansion of TSP.

2.5.2 Future Procurement

As additional funding becomes available, expanded coordination among partner agencies will be required to further refine Transit Signal Priority (TSP) operations and implement targeted signal timing adjustments aimed at reducing overall traffic delay. The objective remains to improve bus performance while minimizing adverse impacts on cross-street and competing traffic movements. As TSP data volumes and system logs continue to grow, several strategic system enhancements are being planned.

NYCDOT is currently conducting TSP pilot initiatives to evaluate extended priority duration limits and reduced progression speeds, assessing their effects on corridor performance and traffic operations. In parallel, MTA is exploring future Machine Learning (ML)–based solutions, such as "Intelligent TSP," which seek to enhance the existing system through conditional priority strategies, differentiated priority levels, and data-driven parameter optimization. These approaches rely on expanded data collection and performance analytics to provide dynamic, network-wide operational insights and support data-informed decision-making.

To support these advancements, potential procurement options include software enhancements to improve system intelligence, scalability, and analytics, along with optimized information exchange to strengthen coordination between NYCDOT and MTA systems. Firmware upgrades may also be considered to address limitations related to simultaneous bus priority requests and to support advanced features such as TSP-enabled left-turn phase insertion.

Looking ahead, future task orders, such as Adaptive TSP, are expected to encompass the design and implementation of adaptive priority strategies incorporating simulation modeling, video analytics, and machine learning capabilities. The diversity of funding sources and technical components underscores the importance of strong project management and sustained coordination across city, state, and federal agencies to ensure successful procurement, deployment, and long-term system performance.

2.6 Applicable ITS Standards and Testing Procedures

This section discusses the ITS standards adopted for the deployment and the testing program.

2.6.1 Project Standards

The stakeholders have adopted the following NTCIP standards for this project. This list identifies the standard and specific version for the project. Note that the NTCIP standards are subject to change over the life-cycle of this project. Specific versions have been adopted to limit the impacts of any changes.

Table 1: Project Standards – NTCIP

Standard	Version (Project)	Title
NTCIP 1103	v03.52	Transportation Management Protocols
NTCIP 1201	v03.15	Global Objects Definitions
NTCIP 1202	v02.3A	Object Definitions for Actuated Traffic Signal Controller Units
NTCIP 1211	V2.24	Object Definitions for Signal Control and Prioritization
NTCIP 2301	V2.19	Simple Transportation Management Framework Application Profile

To design a solution for the TSP operations, a number of requirements were generated that communicated specific data items between the various system components. The above standards provide the basic data objects necessary to satisfy these derived data requirements. The standards also describe the standard message dialogs governing communications between the distributed components of the system. The standards are stable and widely used by the industry's technology vendors.

While these standards have been adopted for the project, the object definitions do not encompass all information that has been identified as being necessary to accomplish the project objectives. For example, the standards do not utilize objects that identify specific transit vehicles nor routes. Therefore, the project supplemented the standard objects with custom objects. These additional objects are documented in the same manner as the standard objects and maintained so that the communications interfaces remain open. In addition, due to the wireless nature of the networks, mechanisms are used to create block objects that reduce the communications bandwidth and processing required while maintaining the integrity of the NTCIP objects where possible.

The NTCIP standards above and transit vehicle standards below facilitate meeting the requirements found in Appendix A (Requirements Table).

Standards have also been adopted regarding the transit vehicle equipment and its operation. These standards are listed in the following table.

Table 2: Project Standards – Transit Vehicle Equipment

Standard	Version (Project)	Title	Version (Current)
SAE J1455	Unspecified	Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications	Same
SAE-J551	1995-07	Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices (30 to 1000 MHz) (Refer also J1816)	Cancelled 2010
SAE J1127	Unspecified	Low Voltage Battery Cable	2012-10
SAE J1128	Unspecified	Low Voltage Primary Cable (Work in Progress)	
IEC 61000-6-2	1.0 1999-01	Part 6-2: Generic standards - Immunity for industrial environments	2.0 2005-01
IEC 61000-6-3	1.0 1996-12	Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments	2.1 2011-02
47 CFR 15	Unspecified	Code of Federal Regulations, Title 47 Telecommunications - Part 15 Radio Frequency Devices (for Class A and Class B devices)	
IET BS7671	17 2008	Requirements for Electrical Installations (Note: British Standard for low voltage installations in buildings. Referred to in TSP spec as "IEEE Wiring Regulations 17th Edition" in the TSP - Addendum 1 - TECHNICAL SPECIFICATIONS)	Same
NMEA 0183	Unspecified	Electrical interface and messaging protocol utilized by GPS devices. (RS-422 bus)	v4.10
NMEA 2000	Unspecified	Electrical interface and messaging protocol utilized by GPS devices. (CAN bus)	v3.00
IETF SNMP	v3	Simple Network Management Protocol	
MIL-STD-810	D 1983-07	Environmental Engineering Considerations and Laboratory Tests (shock & vibration)	G 2008-10
NIST SP 800-123	Unspecified	Guide to General Server Security	
NIST SP 800-44-2	Unspecified	Guidelines on Securing Public Web Servers	
	Unspecified	128-bit Secure Socket Layer encryption	

2.6.2 Testing Procedures and Performance Monitoring

The TSP architecture consists of a real-time, embedded communications system. While a portion of the communications infrastructure is not embedded (the fleet management server to the priority interface server), this portion has real-time constraints for message processing.

NYCDOT and MTA NYCT have expanded TSP implementation across numerous bus corridors in all five boroughs. To assist with the deployment, fine tuning and monitoring of many TSP bus corridors, NYCDOT automated the performance monitoring reports. Due to the real-time nature of TSP operations, performance analysis relies heavily on detailed logging of message traffic stored in NYCDOT's Traffic Management Center (TMC) ITS data warehouse. Postprocessing of archived data is used to generate systemwide performance monitoring reports. Post-evaluation analysis merges multiple system logs to create a unified operational "picture," representing either individual transit vehicle movements or aggregated route-level operations over defined analysis periods.

This framework includes a citywide TSP dashboard, daily system message reports, message integrity validation, mobility analytics, and an operations management dashboard. Automated daily email alerts further support continuous verification of data quality and system health. Together, these tools are now integral to both strategic decision-making and day-to-day operational management of the TSP program.

Initially a comprehensive TSP performance evaluation framework has been established to assess corridor-level effectiveness. Key performance indicators include bus travel time, schedule adherence, on-time performance, and a wait-assessment metric that measures compliance with established bus spacing standards. Signal delay analyses evaluate the share of buses arriving during green signal phases versus those experiencing delay, along with the associated average delay duration. Current performance monitoring emphasizes indicators such as MTA bus travel time, signal delay percentage, schedule adherence, and overall vehicle delay to provide a holistic view of operational impacts.

Additional testing and evaluation efforts are underway to address more advanced operational scenarios. These include dedicated studies examining simultaneous priority requests from multiple buses and the impacts of left-turn phase insertions. NYCDOT also conducts structured before-and-after TSP studies, comparing 10-day periods with TSP deactivated to 10-day periods with planned TSP parameters activated on each route segment. This approach captures complete bus request-to-clearance message sequences at the intersection level, allowing precise measurement of changes in red-phase waiting time, TSP service duration, and the probability of green-phase progression once a TSP request is initiated.

From these analytical views, performance statistics are generated to assess system behavior. Metrics include communication throughput between buses and traffic signals, signal timing modifications enacted at intersections, transit travel time changes along corridors, stop patterns, and the effectiveness of check-in zones used to trigger priority requests. NYCDOT has developed multiple standardized performance monitoring reports to support these evaluations and inform continuous improvement of the TSP program.

Below are performance monitoring reports that NYCDOT has developed.



Figure 14: Bus Route Summary Performance Report

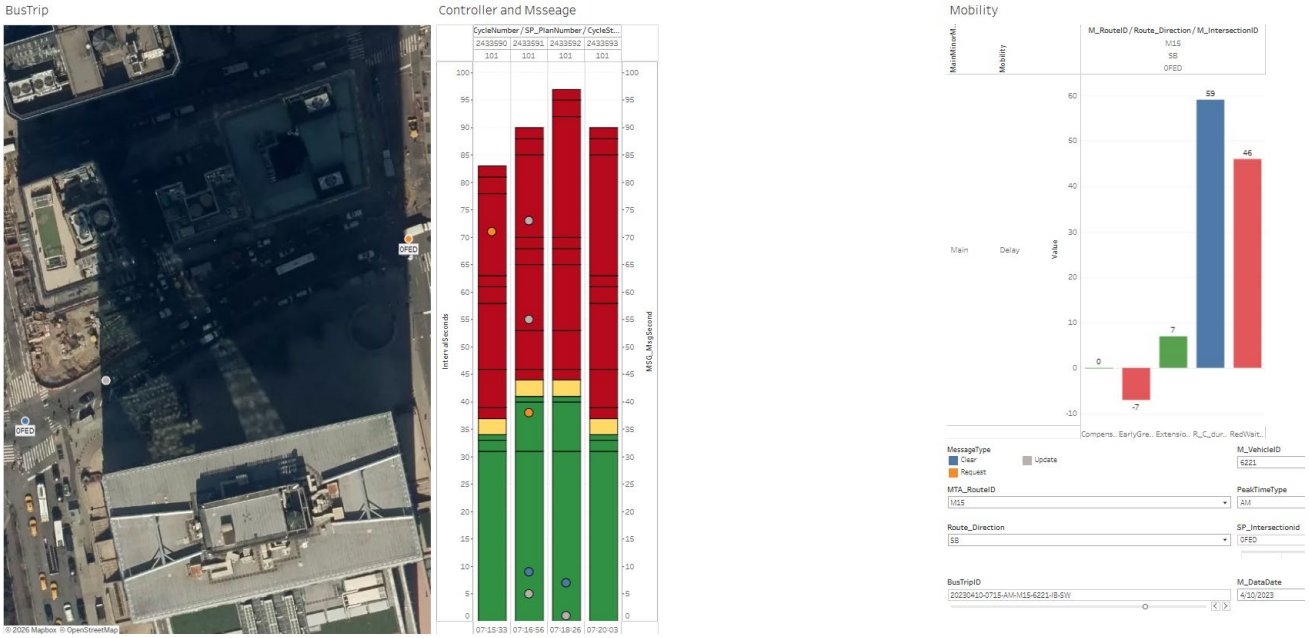


Figure 15: Single Bus Run with TSP Requests within Traffic Controller Timing Cycles

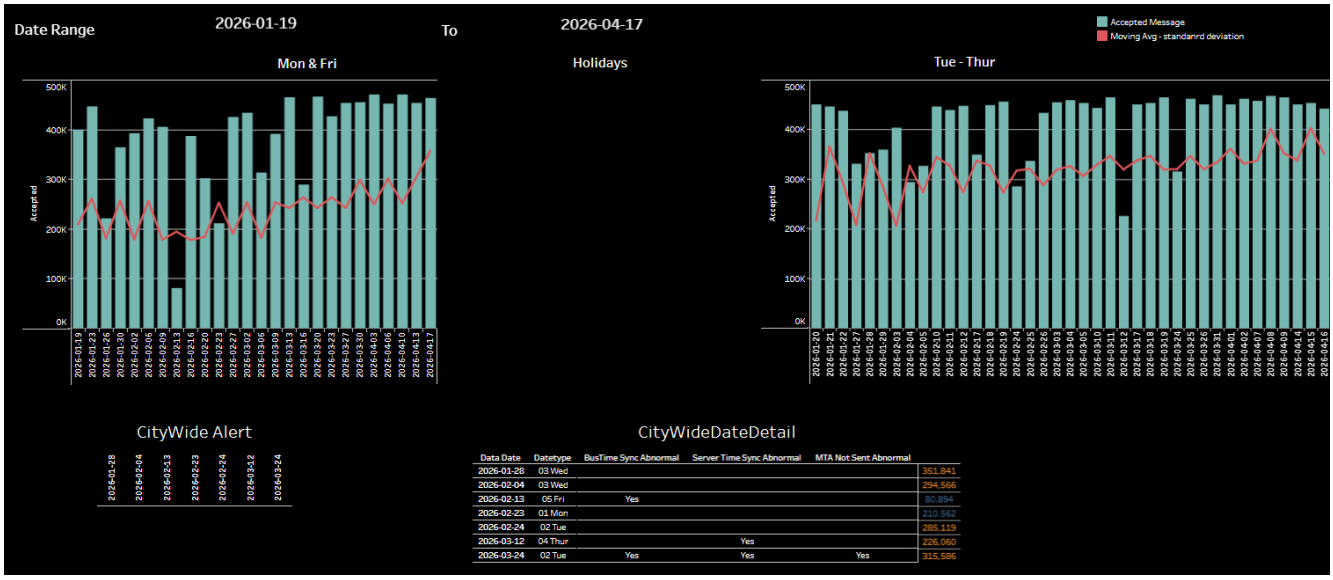


Figure 16: TSP City-Wide Daily Report (Accepted Messages Activity)

In the future NYCDOT will develop a near-real-time dashboard to monitor operations of multiple TSP bus corridors.

2.7 Procedures/Resources Necessary for System Operations and Management

The NYC DOT retained JHK Engineering, P.C. (JHK) to provide a Central TSP module. This module, developed by TransCore ITS, LLC, ran on a dedicated TMC TSP Server and was tightly integrated with the pilot M15 and subsequent bus routes. In February of 2018, the City's Traffic Control System was transitioned to a virtual environment along with the TSP services which formerly ran on a dedicated server. The virtual environment requires on-going maintenance by NYC DOT.

The NYC DOT also retained Greenman-Pederson, Inc. (GPI) and KLD Engineering, P.C. to perform before-after studies, including evaluating and determining which intersections were good candidates to grant TSP to buses.

NYCT retained Global Traffic Technologies (GTT)(now Miovision Technologies) to develop the NYCT TSP server and to integrate it with NYCT bus equipment. This server will require maintenance by NYCT. NYCT also leases an Ethernet Private Line which was upgraded from 10Mbps to 100Mbps on October 2018, from a commercial communications company to provide communications between the TMC and NYCT TSP servers. Both NYC DOT and NYCT will need to support their respective networks to support the connectivity between the TMC and NYCT TSP servers.

Transit signal priority data management is the maintenance activity that requires significant user action by both the NYC DOT and NYCT. The data comprises the following areas:

- Geometric, geographic, and traffic speed data for the derivation of check-in zones
- Check-in zone locations
- TSP configuration loaded into each transit vehicles along routes selected for TSP operation
- TSP traffic signal plans loaded into each traffic signal controller
- TSP strategies loaded into each controller and requested by transit vehicles
- Log information generated by the system during its daily operation. These logs will be used for initial system testing and on-going TSP system evaluation. They include MTA message logs, DOT message logs and intersection traffic signal controller split logs.

The data are necessary for configuring the system's operation. They are required for each intersection configured for TSP operation and are a function of the number of approaches to the intersection that will provide priority operations. The check-in zones (and their data inputs) are assembled and calculated by signal timing engineering staff. The check-in zone data, known as TSP parameters, is transmitted from the engineering personnel to the fleet management server for loading onto the transit vehicles. During 2019, a data interface was implemented to automate the transfer of TSP parameters from the DOT to NYCT. The trigger point definition system transmits route data to an SFTP server accessible by the MTA. NYCT can then retrieve the trigger point definitions for all routes and convert them into the appropriate format for distribution to buses. The NYC DOT traffic signal timing engineers are responsible for the generation, loading, and management of the TSP strategies loaded into individual traffic signal controllers. The NYCT fleet engineering staff is responsible for ensuring the transit vehicles are configured to request the appropriate strategy based on the specific route and intersection approaches. These relationships are shown below in Figure 17 at a high level of abstraction.

Once the transit vehicle, TMC and NYCT TSP servers, and traffic signal controller databases have been configured and validated, they will need to be maintained to include current configuration data. It is anticipated that the TSP system will need to be fine-tuned over time. Additionally, there are facilities for NYC DOT and NYCT operators to override and disable TSP operations when external events such as traffic incidents, severe traffic congestion, or transit route detours occur.

The log information is collected by the system in five locations:

1. Transit vehicles
2. Fleet management server
3. Priority interface server
4. Traffic control system
5. Traffic signal controller

This data must be combined and cross-referenced to generate an accurate "picture" of the operation involving a single transit vehicle or the transit vehicles along a route.

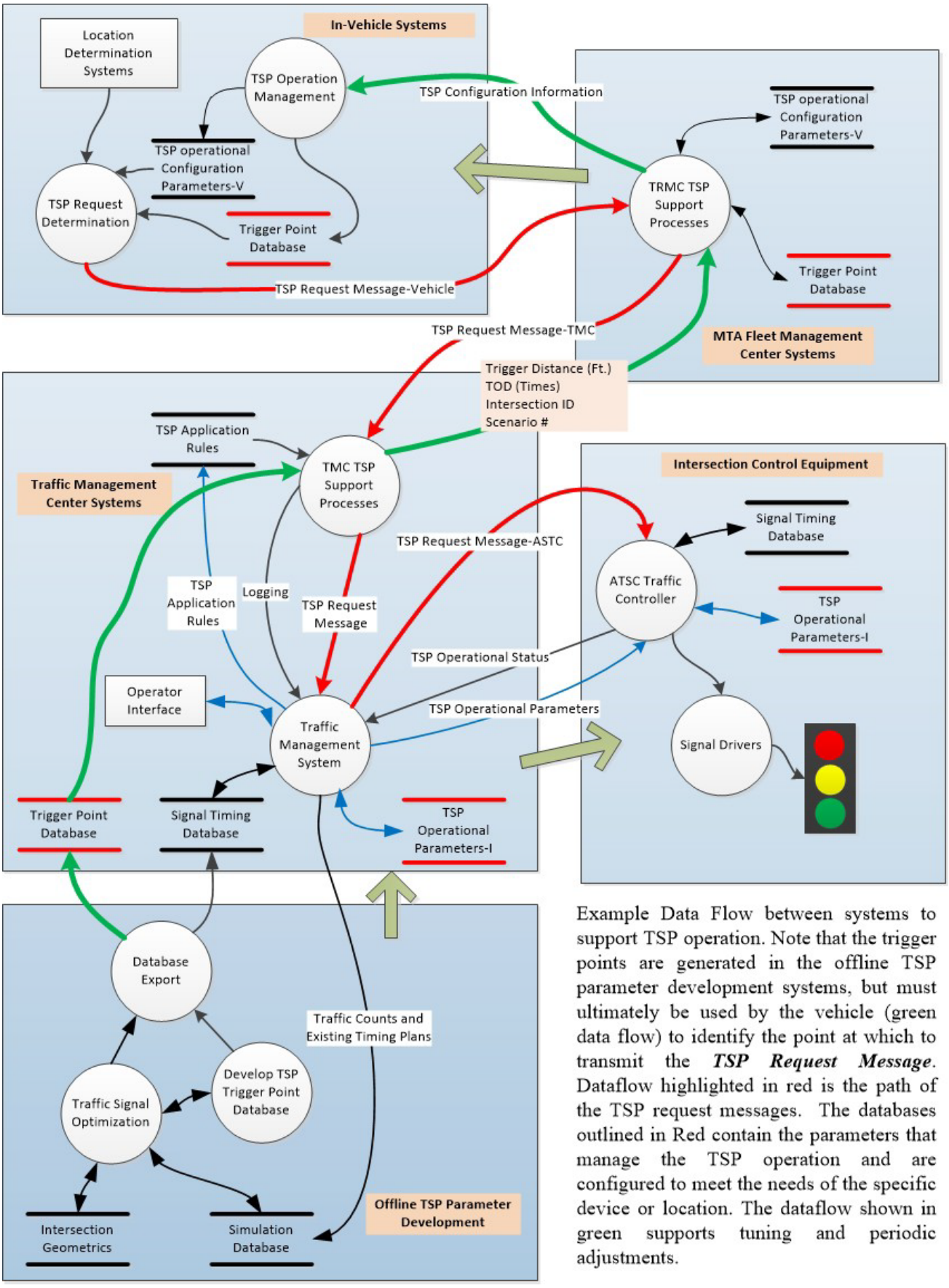
Identifying operational issues and failures is challenging due to the embedded nature of the system operations and the real-time performance requirements. To address this challenge the system has requirements for extensive data logging. Post-processing of log information will be necessary to assess system operation and identify failures. The post-processing will have to examine the number of requests received against the expected requests. This maintenance activity will encompass processing as described in Section 2.6.2 Testing Procedures.

With the expansion of central TSP on additional NYCT bus routes in the City's five boroughs, the NYC DOT has retained JHK to:

- Provide ongoing analysis of the operational integrity of the TSP system
- Develop tools to manage the setup and testing of operational TSP parameters
- Develop a data exchange mechanism to provide operational TSP data necessary for system evaluation
- Provide operational TSP parameters to the NYCT TSP server
- Develop a TSP system data configuration plan

The NYCT has also supported the implementation of central TSP on additional City bus routes.

Warranty in earlier phases of TSP where hardware was installed on 248 buses will expire at its intended maturity date. The hardware will then be retired and replaced with the new generation of TSP software. The software is maintained by the MTA and its contractor(s). Such warranty of licensing agreements cover the application for the life of the bus.



Example Data Flow between systems to support TSP operation. Note that the trigger points are generated in the offline TSP parameter development systems, but must ultimately be used by the vehicle (green data flow) to identify the point at which to transmit the ***TSP Request Message***. Dataflow highlighted in red is the path of the TSP request messages. The databases outlined in Red contain the parameters that manage the TSP operation and are configured to meet the needs of the specific device or location. The dataflow shown in green supports tuning and periodic adjustments.

Figure 17: TSP Functional Block Diagram

2.7.1 Transit Signal Priority Project Costs

Capital and Annual Operating Costs are shown on the tables below. The costs include all TSP corridor deployments to date. The costs include work to support the deployment of Central TSP on additional routes in the five City boroughs.

Not included are the costs associated with the use of existing infrastructure. For the NYC DOT, this includes the Traffic Control System, wireless communications and intersection traffic signal controllers. For NYCT, this includes transit vehicle equipment shared with the Bus Customer Information System: a wireless communications modem, a wireless antenna and an enhanced Global Positioning System (GPS) device.

2.7.1.1 Capital Costs

The current TSP system has been operational since 2013 and the primary capital costs associated with the TSP system are costs incurred to deploy new routes each year. In addition, there are anticipated costs associated with deployment of Adaptive TSP on Pilot Corridors.

Table 3: TSP System Capital Costs Associated with Adaptive TSP

NYC DOT	Consultant services: New route deployment D	$614,000
NYC DOT	Adaptive Central System Development	$155,729
NYC DOT	Adaptive Online Model Development	$157,968
NYC DOT	Adaptive TSP Pilot Corridor Deployment and Testing	$205,906
NYC DOT	Adaptive TSP Planning (OOD-08)	$609,554
NYC DOT	Adaptive System Test Plan Development	$718,384.60
NYC DOT	Adaptive Concept Planning	$158,486
NYC DOT	Adaptive Offline Simulation Model and Scenario Testing	$340,907
NYCDOT	Video Analytics Procurement	$200,000
	Total	$1,943,157

2.7.1.2 Annual Operating Costs

Costs associated with the annual operations and maintenance of the Central TSP System include:

Table 4: TSP System Annual Operating Costs

Agency	Description	Cost
NYC DOT	In-house staff to manage the Central TSP System	$85,000
NYC DOT	Consultant services: To support system operations and maintenance	$200,000
	Total	**$487,392**

2.8 Risk Analysis

This section assesses the project's risks in accordance with FTA characteristics. Some of the risk assessments vary based on the applicable portion of the system architecture that they address. These are shown by two statements for the risk, each statement beginning with the organization addressing the risk.

2.8.1 Risk Characteristics

Table 5: Risk Characteristics

	Characteristic	Description
1	Jurisdiction	Does the ITS project include a single or multiple jurisdictions? Multi-jurisdictional – The City of New York Department of Transportation and the Metropolitan Transportation Authority/New York City Transit (due to the multiple organizations although their geographic area overlay one-another) Assessment: There is little risk as both organizations have been working closely together with well-defined responsibilities and interface between the organizations.
2	Software	Does the project require software development or can rely entirely on existing and proven software? Assessment: This project incorporated existing software and interfaces as well as developed new software. The existing software and interfaces are in place providing communications between the TMC and the traffic signal controllers. New software was developed for communications between the transit vehicles and the fleet management server as well as between the fleet management server and the priority interface server. The traffic signal controller software was modified to implement the TSP requests via its communication interface (this was an addition to the existing input of TSP requests through the signal cabinet electrical connections) and the traffic control system required the development of message handling and logging software to incorporate TSP into the existing traffic control system. This software development has been completed, tested and validated. The well-defined data flow and selection of the NTCIP standards for communication signaling provide a simple interface between the organizations. A new software data interface was developed to automate the forwarding of TSP parameters from the DOT to NYCT. It was completed, tested and validated in 2019. Data Interface is currently used to forward TSP parameters from DOT to NYCT. Software development is a low risk area for this project.
3	Hardware	Does the project require development of hardware or does proven hardware exist? Assessment: **DOT:** The NYCDOT has been utilizing the traffic signal controller hardware (ASTC) for almost a decade with minor modifications over the time period. The operation of the ASTC was lab tested for TSP operation. **MTA:** The transit vehicle hardware exists and additional embedded software to perform the communications and TSP functions was completed, tested and validated in 2018. Hardware development is a low risk area for this project.

	Characteristic	Description
4	Interfaces	Does the project require new interfaces or will it rely entirely on existing interfaces? Assessment: **DOT:** The project utilizes an existing NTCIP communications interface to communicate with the traffic signal controller. It required some additional custom objects to supplement existing objects to support the remote TSP requests. These new objects were straight forward to define and utilize. The interface between the priority interface server and the traffic signal controller utilized the existing wireless communication infrastructure and security mechanisms (i.e. VPN tunnels, encryption). **MTA:** A new interface between the transit vehicle and the fleet management server was developed, tested and validated. The communication between the transit vehicles and the fleet management server have a limited message set and thereby limit risk. **DOT/MTA:** The servers reside on different, isolated, private networks. Network, routing and firewall rules will have to be carefully configured to connect the servers and maintain the isolation of other network communications. The communications between the fleet management and the priority interface servers utilize SNMP/UDP which are existing and well known standards. While the interfaces are well defined and understood, establishing the communication media connection between networks required more time and effort. The details matter and the security of the individual networks were not jeopardized. Development of interfaces is a low risk area for this project.
5	Requirements	Will the project's requirements be well defined and fully documented prior to procuring the system? Assessment: **Yes.** Note that most requirements were implemented within a project Phase 1 and Phase 2 with other requirements slated for future project phases. These are identified in the requirements table in the appendix. The project team have spent considerable resources to develop an adequate set of requirements and consider this characteristic to be a low risk.
6	Procedures	Will the project's operating procedures be well documented prior to procuring the system? Assessment: **Yes.** The data management issues are outlined above in Section 2.7, System Operations. The current project initiated the procedures for collecting, deriving, loading, and managing the configuration data necessary for TSP operation. This provided the raw log information that was used for assessing system operations. Later project phases utilized the lessons learned from these efforts to provide improved tools for performing these activities. This is an area of low risk as TSP Analysis Reports were initially developed in Phase 1 and with continued development during Phase 2 with the collection and analysis of TSP data.

	Characteristic	Description
7	Technologies	Does the project only use proven and stable technologies? Assessment: The project relies upon existing technologies and systems. The traffic control system elements have been in operation for over ten years. The newest technology risk is associated with improving the transit vehicle location by augmenting the GPS based location technologies with parallel dead-reckoning algorithms to supplement the vehicle location during loss of GPS signals. This area had significant risk due to the history of previous attempts to locate vehicles in NYC's canyons. In Phase 2 the risk is now considered low after successful operation of bus location data. The parallel application of the locating algorithms reduced the risk.
8	Staff experience	Does the staff implementing the project have prior experience with ITS procurement, implementation and operations? Assessment: The NYCDOT has extensive experience with the NTCIP standards and their application within the TSNcommunications infrastructure. The MTA has gained considerable recent experience with its open-standards based Bus Time system and communications with its vehicles. The project team and technology contributors have the experience necessary to lower project risk and to deal with issues as they arise. This is a low risk area based on the experience gained from the deployment of the M15 pilot project in Phase 1 and additional routes in Phases 1 and 2.

2.8.2 Risk Mitigation

The MTA and NYCDOT developed a pilot project and verified the hardware and software concepts before proceeding with the procurement of the fleet hardware. One of the significant risks to be addressed was the communications between the vehicles and the transit center. Tests were performed early in the pilot to test the operation of 3G and 4G wireless services. Analysis of the preliminary test results indicated that 4G is a viable choice with the network delays within acceptable limits.

The pilot project also allowed the parties to work out the rules for firewalls, port and networking assignments, data formats, and parameters. This is a key to obtaining the desired connectivity between the owning agencies and minimizing communication latencies.

NYCDOT has already spent extensive time in their ITS laboratory working with JHK and Peek Traffic to test and verify the traffic controller operation with TSP local inputs and with limited remote activation TSP inputs. This experience enabled the pilot project to proceed with its focus on end-to-end communications and operations instead of basic TSP operations in the traffic signal controller.

Finally, the pilot project provided data to analyze signal timing plans and effects of the TSP operation. These analyses will be performed by DOT to ensure that the deployment of TSP would not adversely affect “normal” traffic along the test corridor.

The lessons learned from the pilot program in Phase 1 were included in the MTA procurement program and the final software development for NYCDOT’s priority interface server located at the TMC. Phase 2 has successfully extended the deployed corridors in all five NYC boroughs with more planned in subsequent project phases.

Current Operational Risk: Following the successful Phase 2 deployment, NYCDOT has expanded Transit Signal Priority (TSP) corridors across all five New York City boroughs. NYCDOT continues to evaluate approximately 750–1,000 intersections annually for TSP eligibility. As a result, more than 4,000 intersections—roughly 30 percent of all intersections managed under the Traffic Control System (TCS)—are expected to support TSP in the near term, with long-range projections indicating up to 6,000 TSP-enabled intersections once approximately 8,000 locations are evaluated. This scale of deployment introduces significant operational, technical, and data-management risks that must be proactively mitigated.

As the system expands, scalability has become a critical consideration. The increasing volume of TSP data like spanning message logs, performance metrics, and reporting outputs has placed growing demands on data collection, archiving, and analytics processes. Report generation and dashboard production have required progressively more processing time, creating potential risks to timely performance monitoring and operational decision-making. To mitigate this risk, the Traffic Management Center (TMC) provisioned new servers to host the TSP data warehouse and SQL database. With support from JHK, NYCDOT successfully migrated from legacy infrastructure to the new environment, significantly improving reporting performance and system reliability. However, additional computational methods will be required to sustainably support system growth to thousands of TSP-enabled intersections.

Operational monitoring remains in another critical risk area. As part of earlier evaluations, NYCDOT identified a timing discrepancy between bus onboard systems and the MTA Communications Management Server, which resulted in rejecting TSP requests within TCS. Although this issue was resolved through server upgrades implemented by MTA in early 2023, continued system expansion increases exposure to similar synchronization and communications risks. Ongoing monitoring and validation of time alignment and message integrity between NYCDOT and MTA systems will remain essential as system scale and complexity increase.

Field configuration management also presents an operational risk as the number of TSP intersections grows. Maintaining accurate TSP parameters requires close coordination whenever signal timing plans are modified. If timing changes affect available green extensions or maximum allowable TSP duration, the ITS Unit must be promptly notified to adjust estimated time-of-arrival (ETA) and distance parameters and communicate these updates to MTA. Failure to maintain timely parameter alignment could degrade TSP performance or result in unintended traffic impacts.

Advance Pilot Deployment Risk:
Looking ahead, NYCDOT anticipates deploying Adaptive TSP and introducing Artificial Intelligence and Machine Learning–based capabilities. These initiatives carry additional technology and integration risks. Planned efforts include developing a robust data pipeline for continuous access to MTA vehicle location data, designing predictive arrival time algorithms that leverage historical and real-time inputs, upgrading roadside communications infrastructure, and implementing advanced signal control algorithms capable of forecasting traffic impacts prior to executing TSP requests.

To mitigate these risks, NYCDOT will require validation of software concepts and system architectures prior to procurement and deployment. One of the most significant emerging risks lies in system interoperability, specifically, the reliability of real-time communications between MTA vehicle location systems, NYCDOT data platforms, new adaptive signal control algorithms, and TCS-based TSP request handling. Addressing these risks will require rigorous interface testing, clearly defined data governance protocols, and close interagency coordination to ensure system resilience as TSP capabilities and scale continue to evolve.

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3. Glossary

Revenue Status: Indicates whether a transit vehicle's trip involves collecting fares. When fares are being collected, the trip is considered to be a revenue trip and the vehicle is referred to as being in- service. Trips made without collecting fares are non-revenue trips and the vehicle is referred to as being out-of-service. Non-revenue trips involve travel to maintenance facilities or from maintenance yards to a route's starting point and vice-versa.

Check-in Zone: A check-in zone is the geographic "trigger point" for initiating a transit signal priority request. The trigger point is calculated to be a point some distance upstream of the intersection's stop bar based on the average vehicle speed under expected traffic conditions. The trigger point defines the beginning of a geographic area in which the vehicle should generate a request and subsequent updates until it passes over the intersection's stop bar. Note that the trigger point is actually any point on a line perpendicular to the roadway located at the specified distance from the center of the stop bar.

Check-Out Zone: A location in an intersection where a moving bus no longer needs a green signal to proceed through the intersection. A TSP-enabled bus sends a 'clear' message when it reaches this point. In practice this is a point, not a zone, but is named as such to better pair it with 'check-in zone'.

Proximity Zone: A proximity zone is the geographic area approaching an intersection within which requests and updates are considered to be valid. The proximity zone is a significantly larger area than the check-in zone and provides an assurance that the transit signal priority requests and update transactions are being directed to the appropriate intersection.

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4. Acronyms

Table 6: Acronyms

Abbreviation	Meaning
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ATDM	Active Transportation and Demand Management
AVL	Automated Vehicle Location
Bus CIS	Bus Customer Information System
CAD	Computer Aided Dispatch
CES	Central Electronic Shop
CFR	Code of Federal Regulations
CISPR	Comité International Spécial des Perturbations Radioélectriques (a.k.a. International Special Committee on Radio Interference)
CMAQ	Congestion Mitigation and Air Quality Improvement Program
DoB	Department of Buses
DoITT	Department of Information Technology and Telecommunications
DOT	Department of Transportation
DRU	Dead Reckoning Unit
DSC	Destination Sign Code
DSRC	Direct Short-Range Communication
EMD	Electronic Maintenance Division
EPL	Ethernet Private Line
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GPI	Greenman Pedersen Inc.
GPS	Global Positioning System
GTT	Global Traffic Technologies
ICM	Integrated Corridor Management
IEC	International Electrotechnical Commission
IEE	Institution of Electrical Engineers (British)
IEEE	Institute of Electrical and Electronics Engineers (American)
IET	Institution of Engineering and Technology (f.k.a. IEE)
IETF	Internet Engineering Task Force
ITS	Intelligent Transportation Systems
JHK	JHK Engineering, P.C.
LTD	Limited
MTA	Metropolitan Transit Authority (of the City of New York)
MTAIT	Metropolitan Transit Authority Information Technology
NEMA	National Electrical Manufacturers Association
NIST	National Institute for Standards and Technology
NITSA	National ITS Architecture
NMEA	National Marine Electronics Association
NRTM	Needs to Requirements Traceability Matrix
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
NYCSRA	New York City Sub-regional Architecture
NYCT	New York City Transit
NYCWiN	New York City Wireless Network
OBE	On-Board Equipment
ODK	Operator Display Keyboard
PSEAR	Project System Engineering Analysis Report
PIS	Priority Interface Server

Abbreviation	Meaning
SAE	Society of Automotive Engineers
SBS	Select Bus Service
SNMP	Simple Network Management Protocol
TCP/IP	Transmission Control Protocol / Internet Protocol
TCS	Traffic Control System
TMC	Transportation Management Center
TSC	Traffic Signal Controller
TSN	Traffic Safety Network
TSP	Transit Signal Priority
TTA	Time-To-Apply
TTL	Time-To-Live
UDP	User Datagram Protocol
WSUS	Windows Server Update Services

5. Bibliography

Table 7: Bibliography

#	Title	Author	Date	Version
1	Transit Signal Priority (TSP) Concept of Operations	MTA/NYCDOT	5/15/2012	0.3
2	Advanced Solid-State Traffic Controller ASTC Procurement Specification	JHK Engineering, P.C. NYC DOT	5/12/2006	2.6
3	Advanced Solid-State Traffic Controller – ASTC – Procurement Specification	JHK Engineering, P.C. NYC DOT	11/17/2009	3.13.3
4	TSP – Addendum 1 – TECHNICAL SPECIFICATIONS	MTA/NYCT	6/18/2012	2
5	NYCDOT Transit Signal Priority Design Document	Peek Traffic	7/1/2009	D
6	Transit Signal Priority Central Based Management System Preliminary Design Document	JHK Engineering, P.C.	2/28/2011	8.4
7	Transit Signal Priority using NYCWiN - Communications Error Handling Considerations (Addendum1)	JHK Engineering, P.C.	3/18/2011	None
8	TSP Request Interface Specification	JHK Engineering, P.C.	05/17/2016	10.0.1
9	Preliminary TSP UI Design	JHK Engineering, P.C.	6/24/2011	3
10	TSP Server Design Overview	JHK Engineering, P.C.	7/14/2011	None
11	NYC TSP UI Design	JHK Engineering, P.C.	8/22/2011	6
12	NYC Transit Signal Priority Server Requirements	JHK Engineering, P.C.	6/15/2011	None
13	GTT Opticom Traffic Signal Priority System Acceptance Test	Global Traffic Technologies	1/2/2013	1.2
14	Lower Manhattan TSP Implementation Parameters (Ed. This document is referenced in the NYCT MTA analysis of trigger points dated May 30, 2013)	Greenman-Pederson, Inc. (Ed. Referenced as GDI in the trigger points analysis)	05/24/2013	None
15	NYCWiN Transit Signal Priority System for New York City, Lower Manhattan Project - Borough of Manhattan - TSP Traffic Design Report "Before" Condition -Main Body	Greenman-Pederson, Inc.	08/23/2013	Draft
16	New York Sub-Regional ITS Architecture	ConSysTec	2018 Update	None
17	TransSuite TCS User Manual	TransCore ITS, LLC		
18	MTA Requirements for Transit Signal Priority System Architecture	MTA/NYCT	7/2/2018	1.0
19	Summary Table of TSP Corridors Deployed and Planned for Future Deployment (MS Excel file dated May 5, 2020)	NYC DOT	May 5, 2020	None

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Appendix A

Requirements

Table

Appendix A: Requirements Table

Key:

Status TTrue – In initial implementation
F Future
Phs 1 In initial implementation
2 Identified for the next project
F Future

Number Series	Requirement Implementation Area
1.xx	Transit Vehicle
2.xx	Fleet Management Server
3.xx	Priority Interface Server
4.xx	Traffic Signal Controller
5.xx	Traffic Control System
6.xx	Communication

Source Document	Bibliography Reference
AstcSpec3	3
ConOps	1
IfcSpec	8
PiRqmt	12
PreDsgn	6
RvwMtg20130911Mod	None (see meeting minutes)
TcsSpec	17
TechSpec1	4
TSP Simulation Study	15

RqmtNbr	Requirement Detail	Trace (Source)	Sts	Phs	Category
1.01	The transit vehicle's TSP system components shall operate when the vehicle's engine is running.	ConOpsPg 25, Sec 6.1	T	1	TV Env
1.02	The transit vehicle's TSP system components shall operate from battery power when the vehicle's engine is powered off and personnel enable power from the battery.	ConOpsPg 25, Sec 6.1	T	1	TV Env
1.03	The transit vehicle's TSP system user interface shall limit access to authorized users.	ConOpsPg 25, Sec 6.1	T	1	TV Mgmt
1.04	The transit vehicle's TSP system user interface shall display its operating parameters.	ConOpsPg 25, Sec 6.1	T	1	TV Mgmt
1.05	The transit vehicle's TSP system user interface shall save operating parameters edited by authorized users.	ConOpsPg 25, Sec 6.1	T	1	TV Mgmt
1.06	The transit vehicle's TSP system components shall log changes to operating parameters.	ConOpsPg 25, Sec 6.1	T	1	TV Mgmt
1.07	The transit vehicle's TSP system user interface shall display and export logs of operations events. The following events shall be logged: TSP request sent TSP update sent TSP clearance sent TSP reply received	ConOpsPg 25, Sec 6.1 RvwMtg20130911Mod	T	1	TV Mgmt
1.08	The transit vehicle's TSP system components shall operate during all trips. During non-revenue trips, priority transactions shall be logged on the vehicle and shall not be transmitted to the fleet management server.	ConOpsPg 13, Sec 4.3.1 ConOpsPg 25, Sec 6.1 RvwMtg20130911Mod	T	1	TV Core
1.09	The transit vehicle's TSP system shall send trip information and operating parameters to the fleet manager server on request of the fleet manager server.	TechSpec1 Pg 8, Sec 2.1.1.2.1	F	F	TV Mgmt
1.10	The transit vehicle's TSP system shall obtain the trip information from the Fleet management server.	ConOpsPg 27, Sec 6.3.1	T	1	TV Core
1.11	The trip information shall consist of the route path, schedule times along the path, a list of TSP equipped intersections along the route path, the geographic coordinates of check-in zone waypoints (i.e. trigger and stop bar points), and travel headings for each TSP equipped intersection, and update message limits for each check-in zone.	ConOpsPg 12, Sec 4.3.1 ConOpsPg 14, Sec 4.3.2 PreDsgnPg 6, Sec 3.1.3 TechSpec1 Pg 6, Sec 1.4.1	T	1	TV Core
1.12	The transit vehicle's trip information shall be loaded from the fleet management server to each transit vehicle's TSP system at the start of each trip.	ConOpsPg 12, Sec 4.3.1	F	2	TV Core
1.13	A trip shall "start" when the Destination Sign Code changes and the new code is one of the valid codes for the current route.	ConOpsPg 13, Sec 4.3.1 TechSpec1 Pg 6, Sec 1.4.1 TechSpec1 Pg 9, Sec 2.1.1.2.2 RvwMtg20130911Mod	T	1	TV Core
1.14	Check-in zone definition parameters shall be configurable on the transit vehicle.	ConOpsPg 13, Sec 4.3.2 ConOpsPg 27, Sec 6.3.3.1	T	1	TV Mgmt
1.15	Check-in zone definition parameters shall be configurable in the database for the fleet management server.	Operation	T	2*	Sys Mgmt
1.16	Check-in zone definition parameters shall be configurable by time-of-day for each intersection.	TSP Simulation Study	T	1	Sys Mgmt
1.17	Each check-in zone shall have an associated configurable priority update message limit. Note: This value limits the number of update messages that a transit vehicle can transmit from within that zone. The default priority update message limit is 3.	ConOpsPg 14, Sec 4.3.2 RvwMtg20130911Mod	T	1	TV Core

1.18	Each transit vehicle priority transaction shall include a message type being one of request, update, or clearance.	IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.19	Each transit vehicle priority transaction shall include the transit vehicle's identification.	PreDsgnPg 6, Sec 3.2.2 PreDsgnPg 15, Sec 4.4.2 IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.20	Each transit vehicle priority transaction shall include the transit vehicle's class type where 1 is for "regular" transit vehicles and 2 is for Bus Rapid Transit vehicles (SBS or Select Bus Service in NYC).	PreDsgnPg 15, Sec 4.4.2 PreDsgnPg 15, Sec 4.4.3 IfcSpecPg 17, Sec 3.1.4	T	1	TV Core

RqmtNbr	Requirement Detail	Trace (Source)	Sts	Phs	Category
1.21	Each transit vehicle priority transaction shall include the transit vehicle's class level where the level is between 1 and 10 inclusively. The default class level shall be 5.	IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.22	Each transit vehicle priority transaction shall include the transaction's origin where 0 indicates the transit vehicle and 1 indicates the Fleet management server.	IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.23	Each transit vehicle priority transaction shall include the target intersection's traffic signal controller cabinet address.	PreDsgnPg 6, Sec 3.1.2 IfcSpecPg 11, Sec 2.3.1 IfcSpecPg 18, Sec 3.1.4	T	1	TV Core
1.24	Each transit vehicle priority transaction shall include the requested target intersection's TSP strategy. Note that one or more TSP strategies may be utilized on a unique intersection's approach in order to provide different TSP operations based on stop locations or transit service needs (e.g. one route needing a left turn priority treatment while another route, on the same approach, needs a through priority treatment).	PreDsgnPg 6, Sec 3.1.3 PreDsgnPg 7, Sec 3.1.5 IfcSpecPg 9, Sec 2.2.1.2 IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.25	Each transit vehicle's priority request and update messages shall include the transit vehicle's route identification.	PreDsgnPg 6, Sec 3.1.6 IfcSpecPg 9, Sec 2.2.1.2 IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.26	Each transit vehicle's priority request and update messages shall include the transit vehicle's location as a latitude and longitude in micro-degrees.	ConOpsPg 8, Sec 3.2 PreDsgnPg 6, Sec 3.1.1	T	1	TV Core
1.27	Each transit vehicle's location shall be reported with an accuracy of +/- 10 feet. Note that at 40 degrees north latitude, the approximate latitude of New York City, 10 feet is equivalent to approximately 27 micro-degrees of latitude, or 36 micro-degrees of longitude.	PreDsgnPg 6, Sec 3.1.1 IfcSpecPg 11, Sec 2.3.2	T	1	Prfm
1.28	Each transit vehicle priority request and update message shall indicate the units for the transit vehicle's speed where 0 indicates Miles Per Hour and 1 indicates Kilometers Per Hour.	IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.29	Each transit vehicle priority request and update messages shall include the transit vehicle's speed in the units specified by the vehicle speed units parameter.	IfcSpecPg 9, Sec 2.2.1.2 IfcSpecPg 17, Sec 3.1.4	T	1	TV Core
1.30	Each transit vehicle speed measurement shall be accurate to +/- 1 unit.	RvwMtg20130911Mod	T	1	Prfm
1.31	Each transit vehicle priority request and update messages shall include the Time-To-Apply (TTA) as the seconds since January 1, 1970 in UTC time.	IfcSpecPg 9, Sec 2.2.1.2	T	1	TV Core
1.32	Each transit vehicle priority request and update messages shall include the Time-of-Service Desired (TSD) in seconds as the delay between the TTA and the vehicle's actual arrival at the intersection.	IfcSpecPg 9, Sec 2.2.1.2	T	1	TV Core
1.33	Each transit vehicle priority request and update messages shall include the Time-To-Live (TTL) as the seconds that the request may remain active after the TTA occurs.	ConOpsPg 13, Sec 4.3.2 IfcSpecPg 9, Sec 2.2.1.2 IfcSpecPg 18, Sec 3.1.4	T	1	TV Core
1.34	Each transit vehicle priority transaction shall include the Request ID.	IfcSpecPg 9, Sec 2.2.1.1	T	1	Sys Mgmt
1.35	The same Request ID shall be included in subsequent transactions for the same intersection	IfcSpecPg 9, Sec 2.2.1.1	T	1	Sys Mgmt
1.36	The Request ID shall increment by one for each TSP equipped intersection along a route path.	IfcSpecPg 9, Sec 2.2.1.1	T	1	Sys Mgmt
1.37	The Request ID shall be in the range of 1-255 inclusive and automatically rollover from 255 to 1. Note: This requirement defines the behavior of Request ID so that each component has a common understanding of the ID and when/how it is reset. This is preferable so that the TSP servers can identify whether there are missing requests.	RvwMtg20130911Mod	T	1	Sys Mgmt
1.38	Each transit vehicle shall transmit priority transactions only during revenue trips.	ConOpsPg 13, Sec 4.3.1 RvwMtg20130911Mod	T	1	Sys Mgmt
1.39	Each transit vehicle shall generate a priority request message when the check-in zone's trigger waypoint is detected.	ConOpsPg 13, Sec 4.3.2 ConOpsPg 40, Sec 9.2.6.1 PreDsgnPg 4, Sec 2.1 RvwMtg20130911Mod	T	1	TV Core
1.40	Each transit vehicle shall generate a priority update message when the vehicle crosses (i.e. as it crosses, or if it has crossed but not yet transmitted the TSP request) a line perpendicular to the roadway at the configured trigger point upstream from the intersection.	ConOpsPg 13, Sec 4.3.2 ConOpsPg 40, Sec 9.2.6.2	T	1	TV Core
1.41	Each transit vehicle shall generate a priority clearance message when the check-in zone's stop bar waypoint is detected.	ConOpsPg 13, Sec 4.3.2 ConOpsPg 41, Sec 9.2.6.3	T	1	TV Core
1.42	Each transit vehicle shall cease generating priority updates for an intersection when it has generated the value set by the check-in zone's configurable priority update message limit.	ConOpsPg 14, Sec 4.3.2	T	1	TV Core
1.43	Each transit vehicle shall communicate its priority transactions to the fleet management server.	ConOpsPg 14, Sec 4.3.3 PreDsgnPg 5, Sec 2.2	T	1	Comm

2.01	The fleet management server shall forward valid priority transactions (requests, updates, clearances) to the priority interface server.	ConOpsPg 14, Sec 4.3.3 PreDsgnPg 5, Sec 2.2	T	1	FS Core

RqmtNbr	Requirement Detail	Trace (Source)	Sts	Phs	Category
2.02	The fleet management server shall consider a priority transaction valid when the transit vehicle transmits a priority transaction during a revenue trip.	ConOpsPg 14, Sec 4.3.3	T	1	FS Core
2.03	The fleet management server shall log each priority transaction, its disposition (i.e. accepted, denied) and the reason for denial when denial occurs.	PreDsgnPg 20, Sec 8	T	1	FS Core
2.04	Each log event of a transit vehicle priority transaction shall include the UTC time adjusted to the local time zone reported to the millisecond	RvwMtg20130911Mod	T	1	Sys Mgmt
3.01	The priority interface server shall log each priority transaction and its disposition (i.e. accepted, denied).	RvwMtg20130911Mod	T	1	PI Core
3.02	The priority interface server shall maintain a user configurable set of proximity zones for each approach of each TSP equipped intersection.	PreDsgnPg 6, Sec 3.1.3 PreDsgnPg 25, Sec 17	T	1	PI Mgmt
3.03	Each proximity zone definition shall be orthogonal to the latitude measurement.	PreDsgnPg 25, Sec 17	T	1	PI Mgmt
3.04	Deleted (See proximity zone in deleted requirements list)				
3.05	The priority interface server shall verify the validity of each priority transaction.	PreDsgnPg 5, Sec 2.2 PreDsgnPg 6, Sec 3	T	1	PI Core
3.06	Each valid priority transaction shall have TSP enabled at each of its associated higher level organizations (intersection, route, jurisdiction, or system).	PreDsgnPg 6, Sec 3.3 PreDsgnPg 22, Sec 10.5 PiRqmt Sec 22.4 PiRqmt Sec 22.3 PiRqmt Sec 22.2 PiRqmt Sec 22.1	T	1	PI Core
3.07	Each valid priority request shall have a transit vehicle location that is within the target intersection approach's proximity zone.	PreDsgnPg 6, Sec 3.1 PreDsgnPg 15, Sec 4.4.6 PiRqmt Sec 22.5	T	1	PI Core
3.08	Each valid priority update shall have a transit vehicle location that is within the target intersection's proximity zone.	PreDsgnPg 6, Sec 3.1 PiRqmt Sec 22.5	T	1	PI Core
3.09	Each valid priority request shall not have an existing priority request at its target intersection.	PreDsgnPg 15, Sec 4.4.3 (priority levels) IfcSpecPg 11, Sec 2.2.5 (send only first)	T	1	PI Core
3.10	Each valid priority request shall arrive at the priority interface server prior to the time defined by the message's TimeToApply plus the TimeToLive. This is an obvious condition – if the TTA+TTL is less than the current time, then it is too late to react and the request should be rejected.	PiRqmt Sec 22.6	T	1	PI Core
3.11	The priority interface server shall provide user selectable validation modes being one of normal, accept all, or reject all. Note that normal implements the validation requirements and the other modes bypass the validation mode as requested. Note: Accept All overrides all other validity checks effectively disabling them.	RvwMtg20130911Mod	T	1	PI Core
3.12	The priority interface server shall grant priority at each intersection to one transit vehicle at any time.	IfcSpecPg 8, Sec 2.2.1.1 (unique def) IfcSpecPg 11, Sec 2.2.5 (send only first per int)	T	1	PI Core
3.13	The priority interface server shall deny priority at an intersection to any additional transit vehicles while another transit vehicle is being granted priority.	IfcSpecPg 11, Sec 2.2.5 (send only first)	T	1	PI Core
3.14	The priority interface server shall communicate valid priority transactions to the target traffic signal controller.	PreDsgnPg 5, Sec 2.3	T	1	PI Core
4.01	The traffic signal controller shall respond to priority requests using a preprogrammed strategy.	AstcSpec3 Pg 170, Sec 7.9.4	T	1	SC Core
4.02	The traffic signal controller shall have a minimum of six strategies (e.g. approach direction, stop type).	PreDsgnPg 5, Sec 2.6 PreDsgnPg 7, Sec 3.1.4 PreDsgnPg 10, Sec 4.2 PreDsgnPg 25, Sec 17 AstcSpec3 Pg 170, Sec 7.9.1.5	T	1	SC Mgmt
4.03	The traffic signal controller shall have a TSP timing modification parameter set for each supported strategy.	AstcSpec3 Pg 171, Sec 7.9.3	T	1	SC Core
4.04	The traffic signal controller shall allow the extension and/or truncation of time for each TSP timing modification parameter set.	AstcSpec3 Pg 171, Sec 7.9.3	T	1	SC Core
4.05	Each traffic signal controller location (i.e. intersection) shall be identified by its cabinet address.	PreDsgnPg 5, Sec 2.7 IfcSpecPg 8, Sec 2.2.1.1 IfcSpecPg 11, Sec 2.3.1 IfcSpecPg 18, Sec 3.1.4	T	1	Sys Mgmt
4.06	The traffic signal controller shall have a control to enable or disable TSP operation.	AstcSpec3 Pg 170, Sec 7.9.1.9	T	1	Sys Mgmt

4.07	The traffic signal controller shall communicate the state of the TSP control value with the TCS.	AstcSpec3 Pg 170, Sec 7.9.1.9	T	1	SC Core
4.08	The traffic signal controller shall communicate to the TCS when it begins and when it terminates a TSP response.	AstcSpec3 Pg 171, Sec 7.9.1.10	T	1	SC Core
4.09	The traffic signal controller shall queue priority requests on a First Sequenced, First Served (FSFS) basis.	AstcSpec3 Pg 173, Sec 7.9.4.c	T	1	SC Core

RqmtNbr	Requirement Detail	Trace (Source)	Sts	Phs	Category
4.10	The traffic signal controller shall allow a new priority request, that is received for a phase/interval that occurs earlier in the sequence than the prior priority request currently being served, to be served first (thereby delaying the original priority request).	AstcSpec3 Pg 173, Sec 7.9.4.c	T	1	SC Core
4.11	The traffic signal controller, while executing a Green Extension Strategy, shall ignore (i.e. delay) all other priority requests until the current transit vehicle clears the intersection or the Green Extension Strategy is terminated.	AstcSpec3 Pg 173, Sec 7.9.4.c	T	1	SC Core
4.12	The traffic signal controller shall terminate any priority request when the time defined by the TTA plus the TTL is less than the current time.	IfcSpecPg 18, Sec 3.1.4	T	1	SC Core
4.13	The traffic signal controller shall log its priority actions.	AstcSpec3 Pg 171, Sec 7.9.2.10	T	1	Sys Mgmt
4.14	The traffic signal controller shall communicate its logs to external systems using NTCIP standard and custom objects over NTCIP protocols.	AstcSpec3 Pg 171, Sec 7.9.2.10	T	1	Sys Mgmt
5.01	The traffic control system shall generate a log when a traffic signal controller reports it is timing according to transit signal priority parameters.	PreDsgnPg 20, Sec 8 TcsSpec	T	1	Sys Mgmt
5.02	The traffic control system shall generate a log when a traffic signal controller reports it is no longer timing according to transit signal priority parameters.	PreDsgnPg 20, Sec 8 TcsSpec	T	1	Sys Mgmt
5.03	The traffic control system shall display intersections that are under TSP timing on the map and on the management user interface.	PreDsgnPg 21, Sec 10.1	T	1	Sys Mgmt
5.04	The traffic control system shall let authorized users manage (create, edit, delete, upload, download) TSP operating parameters for the traffic signal controller.	PreDsgnPg 22, Sec 10.3	T	1	TCS Core
5.05	The traffic control system shall let authorized users control TSP transaction processing by enabling and disabling the processing for each individual intersection, route, jurisdictions, and the system.	PreDsgnPg 6, Sec 3, 3.1.4 PreDsgnPg 22, Sec 10.5	T	1	Sys Mgmt
5.06	The traffic control system shall let authorized users schedule TSP transaction processing control events by intersection, route, jurisdiction, or system.	PreDsgnPg 22, Sec 10.4	T	1	Sys Mgmt
5.07	The traffic control system shall execute scheduled TSP transaction processing control events at the scheduled times.	PreDsgnPg 22, Sec 10.4	T	1	Sys Mgmt
5.08	The traffic control system shall let authorized users set the TSP mode to either of normal, accept all, and reject all messages for individual intersections.	RvwMtg20130911Mod	T	1	Sys Mgmt
6.01	Time shall be reported as UTC time adjusted to the local time zone by the transit vehicle, the Fleet management server, and the priority interface server.	PreDsgnPg 16, Sec 5 (Assumed to have been modified from GPS to UTC local)	T	1	Sys Mgmt
6.02	Time shall be synchronized to UTC time adjusted to the local time zone for the transit vehicle, the Fleet management server, and the priority interface server.	PreDsgnPg 16, Sec 5 (Assumed to have been modified from GPS to UTC local)	T	1	Sys Mgmt
5.09	Time shall be adjusted by the priority interface server from UTC local to LFC local reference when transmitting it to the traffic signal controller.	PreDsgnPg 5, Sec 2.3	T	1	Sys Mgmt
6.03	The fleet management server and the priority interface server shall log each priority transaction event with the UTC time adjusted to the local time zone, the transaction's parameters, the priority transaction type (request, update, clearance), the transaction disposition (i.e. accepted, denied), and when denied, denial reasons (i.e. invalid, duplicate).	PreDsgnPg 20, Sec 8	T	1	Sys Mgmt
6.04	Intersection IDs (cabinet address) shall be output in logs as a four character hexadecimal string. Note: This output format facilitates analysis between the communications statistics and the MTA server logged data. By carrying the hex code for the intersection in all log entries, detailed analysis can be more easily performed without the need to translate codes between systems.	RvwMtg20130911Mod	T	1	Sys Mgmt
6.05	Communications shall be secure per industry standards. (Ed. The specific industry standards are not identified. Note that the link between the transit center and the TMC is assumed to be secure as required by MTA and DoITT standards. The link between the intersections and the TMC are secured using VPN "tunnels" between the NOC and the street and by a secure link to the TMC from the NOC.	ConOpsPg 27, Sec 6.3.4	T	1	Comm Gen
6.06	Communication destination systems shall acknowledge their successful receipt of a communication message by sending a response acknowledge message to the source system with a response status of request received.	PreDsgnPg 9, Sec 4.1 PreDsgnPg 14, Sec 4.4.1 IfcSpecPg 10, Sec 2.2.4 IfcSpecPg 19, Sec 3.1.4.2	T	1	Comm Gen

6.07	Communication destination systems shall acknowledge their receipt of a communication message with errors by sending a response acknowledge message to the source system with a response status indicating either: invalid protocol version, invalid message type, invalid message length, invalid vehicle ID, no matching message, TSP disabled for the intersection, vehicle outside of configured request area, or request received, accepted, and queued for transmission to an intersection in the field.	PreDsgnPg 14, Sec 4.4.1 IfcSpecPg 11, Sec 2.2.5 IfcSpecPg 19, Sec 3.1.4.2	T	1	Comm Gen
6.08	Communication source systems shall maintain the following message control parameters per system: latency time, delay time, retry counts, and retry limit parameters.	PreDsgnPg 9, Sec 4.1	T	1	Comm Gen
6.09	Communication message control parameters shall be configurable per system.	ConOpsPg 27, Sec 6.3.3.1	T	1	Comm Gen
6.10	Communication access point parameters (i.e. IP address, port number, protocol family) shall be configurable per system.	PreDsgnPg 9, Sec 4.1	T	1	Comm Gen

RqmtNbr	Requirement Detail	Trace (Source)	Sts	Phs	Category
6.11	A communication source system shall wait the delay time and then re-transmit a message when it does not receive an acknowledgement from the destination system within the latency time period from the message transmission and increment a retry count.	PreDsgnPg 9, Sec 4.1 PreDsgnPg 14, Sec 4.4.1 IfcSpecPg 11, Sec 2.2.5	T	1	Comm Gen
6.12	A communication source system shall continue to re-transmit a message until its retry counts exceeds the retry limit.	PreDsgnPg 9, Sec 4.1 PreDsgnPg 14, Sec 4.4.1 IfcSpecPg 11, Sec 2.2.5	T	1	Comm Gen
6.13	A communication source system shall cease transmitting a message when the retry limit is exceeded.	RvwMtg20130911Mod	T	1	Comm Gen
6.14	The elapsed time between receipt of a TSP transaction and the transmission of the corresponding TSP reply (the “processing time”) shall not exceed 50ms.	IfcSpecPg 12, Sec 2.4.1.1 IfcSpecPg 26, Sec 3.2.1 PiRqmt	T	1	Prfm
3.15	The priority interface server shall be capable of processing a minimum of 1000 TSP requests per second, where “processing” means receiving the request, performing any necessary internal processing (including possibly queuing a TSP implementation request for the affected intersection, but not necessarily actually sending such a request), and sending the appropriate reply.	IfcSpecPg 12, Sec 2.4.1.2 PiRqmt	T	1	Prfm
6.15	Log files shall roll-over. A new log file shall be started and the previous log file shall be closed. Previous log files shall be kept for a minimum of 24 hours.	RvwMtg20130911Mod	T	1	Sys Mgmt
6.16	Log files shall have a unique name that incorporates the date of the last event within the file.	RvwMtg20130911Mod	T	1	Sys Mgmt
2.05	The fleet management server shall be capable of processing a minimum of 1000 TSP requests per second, where “processing” means receiving the request, performing any necessary internal processing, and sending the appropriate message.	RvwMtg20130911Mod	T	1	Prfm

Notes:

* While the check-in zones are configurable in the fleet management server, in Phase 1 this is a manual process using scripts. Phase 2 includes a user interface to aid in managing the data.

ADAPTIVE TSP
REQUIREMENTS

Detailed Adaptive Transit Signal Priority requirements will be developed a part of a upcoming task order NYCDOT-JHK ITS ESA Task Order OOD-08 (**Concept of Operations and Design for Pilot Study of Adaptive TSP**
). This document will be updated in parallel during the Task order effort.

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Appendix B

Needs to Requirements Traceability Matrix (NRTM)

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Appendix B: Needs to Requirements Traceability Matrix (NRTM)

UN ID	User Need	Req ID	Requirement
2.5.1.1	Need for transit route's itinerary		
		1.10	TV TSP system obtains trip information from the FMS
		1.11	Trip information content
		1.13	Trip starts with Destination Sign Code change
		6.02	Time synchronization
2.5.1.2	Need for transit vehicle identification		
		1.19	TV priority transaction includes the transit vehicle's identification
		1.20	TV priority transaction includes the transit vehicle's class type
		1.21	TV priority transaction includes the transit vehicle's class level
2.5.1.3	Need for transit vehicle's transit route assignment		
		1.25	TV priority request and update messages include the route identification
		1.26	TV priority request and update messages include location
		1.27	TV location accuracy
2.5.1.4	Need for transit vehicle's revenue (i.e. service) status		
		1.08	TV TSP system components operate during all trips
		1.38	TV transmits priority transactions only during revenue trips
2.5.1.5	Need for transit vehicle's location		
		1.11	Trip information content
		1.13	Trip starts with Destination Sign Code change
		1.16	Check-in zone definition parameters configurable by TOD for each intersection
		1.25	TV priority request and update messages include the route identification
		1.26	TV priority request and update messages include location
		1.27	TV location accuracy
		6.02	Time synchronization
2.5.1.6	Need to know transit vehicles approaching and clearing an intersection		
		1.11	Trip information content
		1.16	Check-in zone definition parameters configurable by TOD for each intersection
		1.18	TV priority transaction includes a message type
		1.23	TV priority transaction includes the cabinet address
		1.24	TV priority transaction includes the TSP strategy
		1.25	TV priority request and update messages include the route identification
		1.34	TV priority transaction include the Request ID
		1.35	Request ID assigned to an intersection
		1.36	Request ID increments by intersection
		1.37	Request ID range

UN ID	User Need	Req ID	Requirement
		1.41	TV generates a priority clearance message
		4.05	TSC location identified by cabinet address
		6.04	Intersection IDs (cabinet address) output format
2.5.1.7	Need for transit vehicle's priority request		
		1.11	Trip information content
		1.18	TV priority transaction includes a message type
		1.39	TV generates a priority request message
		6.02	Time synchronization
2.5.1.8	Need for updating transit vehicle's priority request		
		1.11	Trip information content
		1.17	Check-in zone has configurable priority update message limit
		1.18	TV priority transaction includes a message type
		1.40	TV generates a priority update message
		1.42	TV ceases generating priority updates
		6.02	Time synchronization
2.5.1.9	Need for calculating the transit vehicle's variance from planned schedule		
		1.11	Trip information content
		1.25	TV priority request and update messages include the route identification
		1.26	TV priority request and update messages include location
		1.27	TV location accuracy
		1.31	TV priority request and update messages include the Time-To-Apply
		1.32	TV priority request and update messages include the Time-of-Service Desired
		1.33	TV priority request and update messages include the Time-To-Live
		6.02	Time synchronization
2.5.1.10	Need to determine whether to grant priority request		
		1.19	TV priority transaction includes the transit vehicle's identification
		1.20	TV priority transaction includes the transit vehicle's class type
		1.21	TV priority transaction includes the transit vehicle's class level
		1.31	TV priority request and update messages include the Time-To-Apply
		1.32	TV priority request and update messages include the Time-of-Service Desired
		1.33	TV priority request and update messages include the Time-To-Live
		1.38	TV transmits priority transactions only during revenue trips
		1.43	TV communicates its priority transactions to the FMS
		2.02	FMS considers priority transaction valid
		3.05	PIS verifies validity of each priority transaction
		3.06	Valid priority transaction have TSP enabled at higher level organizations
		3.07	Valid priority request have locations within proximity zone
		3.08	Valid priority updates have location proximity zone
		3.09	Valid priority requests don't have pre-existing priority requests
		3.10	Valid priority requests arrive prior to TimeToApply plus the TimeToLive

UN ID	User Need	Req ID	Requirement
		3.12	PIS grants priority to one transit vehicle at any time
		3.13	PIS denies priority while another transit vehicle is being granted priority
		6.02	Time synchronization
2.5.1.11	Need to communicate granted priority request		
		2.01	FMS forwards valid priority transactions to PIS
		3.14	PIS communicates valid priority transactions to TSC
		3.15	PIS processing performance
		2.05	FMS processing performance
2.5.1.12	Need for traffic signal controller to implement priority request		
		1.28	TV priority request and update message indicate speed units
		1.29	TV priority request and update messages include speed
		1.30	TV speed accuracy
		1.31	TV priority request and update messages include the Time-To-Apply
		1.32	TV priority request and update messages include the Time-of-Service Desired
		1.33	TV priority request and update messages include the Time-To-Live
		4.01	TSC responds to priority requests using a preprogrammed strategy
		4.02	TSC has a minimum of six strategies
		4.04	TSC allows extension/truncation
		6.02	Time synchronization
		5.09	Time adjustments by PIS
2.5.1.13	Need for transit vehicle’s priority clearance		
		1.33	TV priority request and update messages include the Time-To-Live
		1.41	TV generates a priority clearance message
		2.01	FMS forwards valid priority transactions to PIS
		4.08	TSC communicates begin and termination of TSP response
		4.09	TSC queues priority requests
		4.10	TSC allows a new priority request to be served first
		4.11	TSC ignores all other priority requests until
		4.12	TSC terminates any priority request when the time expires
2.5.1.14	Need to control priority to avoid adversely impacting traffic conditions		
		1.01	TV TSP system components operate when engine running
		1.02	TV TSP system components operate from battery power
		1.22	TV priority transaction includes the transaction’s origin
		4.06	TSC has a control to enable/disable TSP operation
		4.07	TSC communicates the state of the TSP control value with the TCS
		5.05	TCS lets authorized users control TSP transaction processing
		5.06	TCS lets authorized users schedule TSP transaction processing control events
		5.07	TCS executes scheduled TSP transaction processing control events
		5.08	TCS lets authorized users set the TSP mode
2.5.1.15	Need for priority activities to appear on existing traffic control system		

UN ID	User Need	Req ID	Requirement
		3.06	Valid priority transaction have TSP enabled at higher level organizations
		4.07	TSC communicates the state of the TSP control value with the TCS
		5.01	TCS generates a log when TSC reports timing according to TSP
		5.02	TCS generates a log when TSC reports timing according to TSP ceases
		5.03	TCS displays intersections under TSP timing
2.5.1.16	Need for reliable communications		
		6.05	Communications security
		6.06	Communication destination systems acknowledge successful message receipt
		6.07	Communication destination systems acknowledge receipt of message with errors
		6.08	Communication source systems shall maintain message control parameters
		6.09	Communication message control parameters configurable
		6.10	Communication access point parameters configurable
		6.11	Communication source system re-transmission
		6.12	Communication source system re-transmission termination
		6.13	A communication source system shall cease transmitting a message when the retry limit is exceeded.
		6.14	TSP transaction reply time
2.5.1.17	Need to evaluate priority operations		
		1.02	TV TSP system components operate from battery power
		1.04	TV TSP system user interface displays operating parameters
		1.06	TV TSP system components log changes
		1.07	TV TSP system user interface displays and exports logs
		1.08	TV TSP system components operate during all trips
		1.09	TV TSP system sends information to the FMS on request
		2.03	FMS logs each priority transaction
		2.04	Log events include the time
		3.01	PIS logs each priority transaction
		3.11	PIS provides user selectable validation modes
		4.13	TSC logs its priority actions
		4.14	TSC communicates logs to external systems
		6.01	Time reporting format
		6.02	Time synchronization
		5.09	Time adjustments by PIS
		6.03	FMS and PIS log each priority transaction event
		6.04	Intersection IDs (cabinet address) output format
		6.15	Log file roll-over
		6.16	Log files name
2.5.1.18	Need to modify priority parameters		
		1.03	TV TSP system user interface limited access
		1.05	TV TSP system user interface saves edited parameters

UN ID	User Need	Req ID	Requirement
		1.12	TV trip information loads from the FMS
		1.14	Check-in zone definition parameters configurable on the transit vehicle
		1.15	Check-in zone definition parameters configurable in the FMS database
		1.16	Check-in zone definition parameters configurable by TOD for each intersection
		1.17	Check-in zone has configurable priority update message limit
		3.02	PIS maintains proximity zones
		3.03	Proximity zone definitions orthogonal
		3.04	Proximity zone definitions configurable by time-of-day (Propose deleting)
		4.03	TSC has TSP timing modification parameter set
		4.04	TSC allows extension/truncation
		4.07	TSC communicates the state of the TSP control value with the TCS
		5.04	TCS lets authorized users manage TSP operating parameters for TSC
		6.08	Communication source systems shall maintain message control parameters
		6.09	Communication message control parameters configurable
		6.10	Communication access point parameters configurable

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Appendix C

Technology

Contributors

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Appendix C: Technology Contributors

The following organizations provided materials and expertise to the New York City agencies for the transit signal priority program.

Global Traffic Technology (GTT) (now Miovision Technologies), an entity specializing in TSP solutions, developed software to interact with the transit vehicle resident Commercial Off-the-Shelf (COTS) hardware components and generate TSP-requests. This software was installed on the existing bus resident equipment, and programmed with the locations of the TSP- enabled intersections. GTT (now Miovision Technologies) was contracted to MTA.

Greenman-Pedersen Incorporated (GPI) and KLD Engineering, PC (KLD) were two engineering organizations, which evaluated the impacts of priority operations on general traffic conditions and develop signal timing for the signals in this corridor. They provided the initial parameters for TSP operations in a selected corridor. GPI's and KLD's services were contracted through the NYCDOT.

JHK Engineering/TransCore ITS, LLC (JHK), provided and supported the traffic signal system. TransCore was responsible for developing the TMC systems to support TSP operations. They integrated the TSP intersections and provide signal timing services. JHK services were contracted through NYCDOT.

ORIUX (Previously Peek Traffic) provided and supported the Advanced Solid-state Traffic Controller (ASTC). They provided the software that implements transit signal priority at each intersection. Peek Traffic was under contract through the NYCDOT.

Commercial Cellular Communications provider (*currently Verizon Wireless*), provided the wireless communications between the transit vehicles and the transit management center. The cellular communications provider was under contract to the MTA.

Commercial Cellular Communications providers (currently AT&T/Sprint Wireless), provide the wireless communications (TSN) between the Transportation Management Center (TMC) and field traffic signal controllers.

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